DATA BOOK FOR CIVIL ENGINEERS

SPECIFICATIONS and COSTS

ELWYN E. SEELYE

VOLUME TWO

SPECIFICATIONS
and COSTS

DATA BOOK for CIVIL ENGINEERS

By ELWYN E. SEELYE

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SPECIFICATIONS and COSTS

ELWYN E. SEELYE

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PREFACE

"Specifications and Costs" is the second volume in the series of "Data Books," of which Volume I is entitled "Design" and Volume III will be called "Field Practice." The first part of Volume II presents, under eleven headings, typical specifications intended to serve as a guide for the practicing engineer.

Most specifications are written by taking some already formulated specification as a guide and altering it to suit the work in hand. Hence an engineer should have available a specification for any item of engineering for which he is likely to need to write one. This specification should be found not only in a bound volume but also in loose leaf so that copies may be altered for retyping or bound in sets without retyping.

Some of the ideals followed in writing the specifications in this volume are as follows:

Since the best bids can be obtained by fair and clear specifications, the author has given definite tolerances or data instead of using the time-"dishonored" formula "first-class workmanship." The present specifications have attempted to attain the utmost brevity consistent with this objective.

A specification is primarily a contract document and as such should definitely tie up materials and workmanship to a certain grade and quality. This may be done by calling for a material such as cement to comform to an A.S.T.M. serial designation, or by calling for a pump to be manufactured by John Doe or equal.

The specification might very well stop at this point, omitting the question of method entirely. However, it is usual and advisable to supplement the clauses referring to grade and quality by certain instructions as to method, i.e., to tell the contractor that he must observe certain precautions and methods—provide frost protection, for example.

Furthermore, it is advisable to call the inspector's attention to some of his own functions, such as the number and type of field tests that he should conduct.

When specifying a grade or quality of material, an A.S.T.M. or other technical specification reference may properly be used as a short cut, but when instructing the contractor or inspector about a method it is not fair or practicable to give a technical reference to a man in the field. Therefore, the author has been careful to include all the necessary information for the field inspector and the contractor's field organization in the specification or by cross reference to Volume III of this data book, entitled "Field Practice." For instance, briefs of sampling methods and field tests are included in the "Field Practice" in order to give the inspector a handy reference on just how to perform a sampling operation or field test.

Thus, these specifications become of educational value to a field inspector as well as an aid to the specifications writer.

These specifications attempt to follow up-to-date practice of the art; also they are written in the active rather than the passive voice. Suggestions in italics guide the specifications writer in making a choice between two materials: for instance, cement lining for a steel pipe is advised for hard water and bituminous lining for soft water.

Loose-leaf copies of these specifications printed on thin paper for blueprint reproduction will be made available if the demand warrants it.

Section VIII of this volume is entitled "Costs." Because the science of engineering is intimately connected with economy, data for engineering design should include knowledge of relative costs. For instance, an engineer is constantly faced with a choice of materials or a choice of plans involving different materials, and in making his selection the cost item of the materials is of paramount importance. In addition to the question of relative costs, an engineer needs a general idea of costs for budget purposes. For example, he should have an idea of the cubic-foot cost of a building, the per capita cost of a treatment plant, or the cost of a driven well.

The difficulties of quoting costs are very great because of the unstable variables involved, such as time changes and differences in localities. Wherever they are available, bid prices, manufacturer's quotations, and contractor's preliminary estimates in a particular locality are to be preferred to quoted costs; nevertheless, an engineer may be greatly hampered in getting out his designs if he must depend on them. For this reason, the costs in Section VIII have been collected and related to the *Engineering News-Record Building, Construction, and Material Indices* and also, in many cases, to a particular location. For instance, if a cost is quoted for the year 1939, comparison of the

Engineering News-Record Building, Construction, and Material Index of 1939 with that of the year in which the engineer is working will provide a corrective factor.

An unusually complete glossary, in which the entries are grouped according to subject matter, concludes this volume.

ELWYN E. SEELYE

April 15, 1946

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ABBREVIATIONS

A.A.S.H.O.	American Association of State Highway Officials
A.C.I.	American Concrete Institute
A.I.A.	American Institute of Architects
A.I.E.E.	American Institute of Electrical Engineers
A.I.S.C.	American Institute of Steel Construction
A.R.E.A.	American Railway Engineering Association
A.S.A.	American Standards Association
A.S.T.M.	American Society for Testing Materials
A.W.P.A.	American Wood-Preservers' Association
A.W.W.A.	American Water Works Association
Fed. Spec.	Federal Specifications
N.L.M.A.	National Lumber Manufacturers Association
P.R.A.	Public Roads Administration

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I

CONTRACT DOCUMENTS

INVITATION TO BIDDERS

Date ____________________

GENTLEMEN:

You are invited to submit a written formal bid on ____ ____________________ for the below described work at the location indicated.

Description: ____.

The bid and other data submitted by bidders will form the basis for the negotiation of a ________________ contract for the work. Bids are to be submitted in proper form, in quadruplicate, as described in the detail specifications. They shall be addressed to: ____
and marked "Proposal for ________________________________," dated ______________ and mailed in time to reach the designated office on ____________________ at ____________, at which time and place bids will be ______* opened and read.

Plans and specifications may be secured at the office of ________________________________ ____________________ on __________________________ at ______________.

Bid bond will *or* will not be required.

Your attention in particular is invited to "Information for Bidders" enclosed, which is to be followed in all respects.

You may be represented at the opening of bids if you so desire.

Very truly yours

____

By: ____________________________

* Insert either "publicly" or "privately."

INFORMATION FOR BIDDERS

1. Date and Place for Opening Proposals. Pursuant to the "Invitation to Bidders", sealed proposals for performing the work will be received by ______________________________.

At the place and time set forth in said notice, they will be ______* opened by ______________________________ and read; the awarding of the contract, if awarded, will be made by ______________________________ as soon thereafter as practicable.

2. Printed Form for Proposals. All proposals must be made upon the blank form of proposal attached hereto, and should give the ______________________________† for the work, both in words and in figures, and must be signed and acknowledged by the bidder, in accordance with the directions in the form of proposal. In order to insure consideration, the proposal should be enclosed in a return envelope furnished by ______________________________ herewith, marked "Proposal," and addressed to ______________________________.

3. Omissions and Discrepancies. Should a bidder find discrepancies in, or omissions from, the drawings or other contract documents, or should he be in doubt as to their meaning, he should at once notify the engineer who may send a written instruction to all bidders.

4. Acceptance or Rejection of Proposals. The ______ reserves the right to reject any or all proposals. Without limiting the generality of the foregoing, any proposal which is incomplete, obscure, or irregular may be rejected; any proposal having erasures or corrections in the price sheet may be rejected; any proposal which omits a bid on any one or more items in the price sheet may be rejected; any proposal in which unit prices are omitted, or in which unit prices are obviously unbalanced, may be rejected; any proposal accompanied by an insufficient or irregular certified check may be rejected.

5. Certified Check. All proposals shall be accompanied by a certified check upon a national or state bank, located in ______________________________, drawn and made payable to the order of ______________________________. The certified check must be enclosed in the same envelope with the proposal.

The amount of the certified check will be ______________________________.

All such certified checks will be returned to the respective bidders within ____ days after proposals are opened, except those which ______________________________ elects to hold until the successful bidder has executed the contract. Thereafter all remaining checks, including the check of the successful bidder, will be returned within ____ days.

6. Acceptance of Proposals and Its Effect. Within ______ days after the opening of the proposals ______ will act upon them. The acceptance of a proposal will be a notice in writing signed by a duly authorized representative of ______, and no other act of ______ shall constitute the acceptance of a proposal. The acceptance of a proposal shall bind the successful bidder to execute the contract and to be responsible for liquidated damages as provided in Paragraph 7. The rights and obligations provided for in the contract shall become effective and binding upon the parties only with its formal execution by ______.

7. Time for Executing Contract and Damages for Failure to Execute. Any bidder whose proposal shall be accepted will be required to appear at the office of ______ in person, or, if a firm or corporation, a duly authorized representative shall so appear, and to execute the contract within ____ days after notice that the contract has been awarded to him. Failure or neglect so to do shall constitute a breach of the agreement effected by the acceptance of the proposal.

* Insert either "publicly" or "privately."

† Insert "lump sum price and alternates and unit prices" or "price for each item and aggregate amount."

The damages to the owner for such breach will include loss from interference with his construction program and other items whose accurate amount will be difficult or impossible to compute. The amount of the certified check accompanying the proposal of such bidder shall be retained by ______________________ as liquidated damages for such breach. In the event any bidder whose proposal shall be accepted shall fail or refuse to execute the contract as hereinbefore provided, ______________________ may, at his option, determine that such bidder has abandoned the contract and thereupon his proposal and the acceptance thereof shall be null and void and the owner shall be entitled to liquidated damages as above provided.

8. Determination of Low Bidder. Except where the owner exercises the right reserved herein to reject any or all proposals, the contract will be awarded by the owner to the bidder who has submitted the lowest bid determined by the sum of the following.

For a Lump Sum Bid.

Base bid.
Algebraic sum of alternatives elected by owner after opening of bids.
Amount of unit price work based on quantities given in proposal form
Amount of management fees called for in proposal.

For a Unit Price Bid.

Sums of unit price work based on quantities given in schedule.
Algebraic sum of alternatives elected by owner after opening of bids.
Amount of management fees called for in proposal.

9. Time for Beginning and Completing the Work. The contractor shall commence the work within ____ calendar days after the date specified in the notice to proceed given to him by ______________________ to commence work, and he shall complete the work within the time specified.

10. Prices. In the event of discrepancy between the prices quoted in the proposal in words and those quoted in figures, the words shall control. The prices are to include the furnishing of all materials, plant, equipment, tools, scaffolds, and all other facilities, and the performance of all labor and services necessary or proper for the completion of the work, except such as may be otherwise expressly provided in the contract documents.

11. Interpretations and Addenda. No oral interpretations shall be made to any bidder as to the meaning of any of the contract documents, or be effective to modify any of the provisions of the contract documents. Every request for an interpretation shall be made in writing and addressed and forwarded to ______.

TYPICAL PROPOSAL
FOR LUMP SUM CONTRACT

Proposal of ____
Name

____
Address

to furnish and deliver all materials and to do and perform all work in accordance with the specifications and contract of ____________________ for the construction of ____________________

____

this work being situated as follows:

____

____

____

To: ______________________

____

____

GENTLEMEN:

The undersigned bidder has carefully examined the form of contract, the general conditions, the specifications, the special conditions, and the drawings for the construction of ____________________

____

hereinbefore described, and referred to in the "Invitation to Bidders" inviting proposals on such work dated ________ ____________________, and also the site of the work, and will provide all necessary machinery, tools, apparatus, and other means of construction, and do all the work and furnish all material called for by said specifications, general conditions, special conditions, and drawings in the manner prescribed therein and in said contract, and in accordance with the requirements of the engineer under them, for the sum of ________ ____________________ with the following additions or deductions for each of following alternatives:

No. 1 ______________________________ $ ______________

No. 2 ______________________________ $ ______________

Unit Prices for Extra Work

This proposal shall be completed by the bidder, with the unit prices written in words and numerals, and the extensions shall be made by him.

For complete information concerning these items see specifications.

Item No.*	Assumed Quantities *	Description of Items and Unit Prices Bid (written in words) *	Unit Prices		Amounts	
			Dollars	Cents	Dollars	Cents

Management Fees for Proposed Consolidated Contracts †

This proposal shall be completed by bidders.

Item No.*	Assumed Amount of Contract *	Description of Contract to be Consolidated *	Management Fee	
			Dollars	Cents

* To be filled in by engineer.

† Used where general contractor takes over management of subcontracts previously awarded.

The undersigned also agrees as follows:

First: To do any extra work, not covered by the above schedule of prices, which may be ordered by the engineer, and to accept as full compensation therefor such prices as may be agreed upon in writing by the engineer and the contractor in accordance with Art. 16, "General Conditions."

Second: Within ____ days from the date of the "Notice of Acceptance" of this proposal, to execute the contract, and to furnish to ____________________ a satisfactory contract bond in the sum specified by ____________________ guaranteeing the faithful performance of the work and payment of bills.

Third: To begin work on the date specified in the "Notice to Proceed," and to prosecute said work in such a manner as to complete it within ____ calendar days.

Accompanying this proposal is a certified check for ______ payable to ____________________ which is to be forfeited, as liquidated damages, if, in the event that this proposal is accepted, the undersigned shall fail to execute the contract and furnish satisfactory contract bond under the conditions and within the time specified in this proposal; otherwise said certified check is to be returned to the undersigned.

Dated ____________________

(*If an individual, partnership, or non-incorporated organization*)

Signature of bidder ____________________
By ____________________
____

Address of bidder ____________________

Names and addresses of members of the firm

____
____
____
____

(*If a corporation*)

Signature of bidder ____________________
By ____________________ ____________________
Name Title

Business address ____________________
Incorporated under the laws of the State of ____________________

Names of officers
- President ____________________ Name Address
- Secretary ____________________ Name Address
- Treasurer ____________________ Name Address

TYPICAL PROPOSAL
FOR UNIT PRICE CONSTRUCTION CONTRACT

Proposal of ____
Name
____
Address
to furnish and deliver all materials and to do and perform all work in accordance with the specifications and contract of ______________________________ for the construction of ______________________________
____
this work being situated as follows:
____
____
____

To: ______________________________
____
____

GENTLEMEN:

The undersigned bidder has carefully examined the form of contract, the general conditions, the specifications, the special conditions, and the drawings for the construction of ______________________________
____
hereinbefore described, and referred to in the "Invitation to Bidders" inviting proposals on such work dated ______ ______________________________, and also the site of the work, and will provide all necessary machinery, tools, apparatus, and other means of construction, and do all the work and furnish all material called for by said specifications, general conditions, special conditions, and drawings in the manner prescribed therein and in said contract, and in accordance with the requirements of the engineer under them.

The undersigned bidder understands that the quantities of work as shown herein are approximate only and are subject to increase or decrease, and offers to do the work whether the quantities are increased or decreased, at the unit prices stated in the following schedule:

Typical Schedule of Prices

This proposal shall be completed by the bidder, with the unit prices written in words and numerals, and the extensions shall be made by him.

For complete information concerning these items see specifications.

Item No.*	Approximate Quantities *	Description of Items and Unit Prices Bid (written in words) *	Unit Prices		Amounts	
			Dollars	Cents	Dollars	Cents
—						

Management Fees for Proposed Consolidated Contracts †

This proposal shall be completed by bidders.

Item No.*	Assumed Amount of Contract *	Description of Contract to be Consolidated *	Management Fee	
			Dollars	Cents

* To be filled in by engineer.

† Used where general contractor takes over management of subcontracts previously awarded.

The undersigned also agrees as follows:

First: To do any extra work, not covered by the above schedule of prices, which may be ordered by the engineer, and to accept as full compensation therefor such prices as may be agreed upon in writing by the engineer and the contractor in accordance with Art. 15, "General Conditions."

Second: Within ____ days from the date of the "Notice of Acceptance" of this proposal, to execute the contract, and to furnish to ________________________ a satisfactory contract bond in the sum specified by ________________________, guaranteeing the faithful performance of the work and payment of bills.

Third: To begin work on the date specified in the "Notice to Proceed," and to prosecute said work in such a manner as to complete it within ____ calendar days.

Accompanying this proposal is a certified check for ________________________ payable to ________________________, which is to be forfeited, as liquidated damages, if, in the event that this proposal is accepted, the undersigned shall fail to execute the contract and furnish satisfactory contract bond under the conditions and within the time specified in this proposal; otherwise said certified check is to be returned to the undersigned.

Dated ________________________

(*If an individual, partnership, or non-incorporated organization*)

Signature of bidder ________________________

By ________________________

____

Address of bidder ________________________

Names and addresses of members of the firm

____

____

____

____

(*If a corporation*)

Signature of bidder ________________________

By ________________________

Name Title

Business address ________________________

Incorporated under the laws of the State of ________________________

Names of officers

President ________________________

Name Address

Secretary ________________________

Name Address

Treasurer ________________________

Name Address

NOTE: The Standard Agreement for Engineering Construction, copyrighted by the Joint Conference on Standard Construction Contracts, is reprinted below by permission of said Joint Conference on Standard Construction Contracts. Additional copies of this document may be obtained by writing to Joint Conference on Standard Construction Contracts, Munsey Building, Washington, D. C.

(Lump Sum)

STANDARD AGREEMENT
FOR
ENGINEERING CONSTRUCTION

(Not designed for use in building construction)

THIS AGREEMENT made the ______________________________ day of ______________ in the

year Nineteen Hundred and ________________ by and between ____________________________

______________________________ hereinafter called the Contractor, and ____________________________

____ hereinafter called the Owner, WITNESSETH, that the Contractor and the Owner for the considerations hereinafter named agree as follows:

Article 1. Scope of the Work—The Contractor shall furnish all of the materials and perform all of the work shown on the Drawings and described in the Specifications entitled

____

(Here insert the caption descriptive of the work as used on the Drawings and in the other Contract Documents)

prepared by ____

acting as and in these Contract Documents entitled the Engineer and shall do everything required by this Agreement, the General Conditions of the Contract, the Specifications and the Drawings.

Article 2. Time of Completion—The work to be performed under this Contract shall be commenced ____________

____________________ and shall be completed ____________________
(Here insert stipulation as to liquidated damages, if any)

Article 3. The Contract Sum—The Owner shall pay the Contractor for the performance of the Contract, subject to additions and deductions provided therein, in current funds as follows: ____________________

____
(State here the lump sum amount, unit prices, or both, as desired in individual cases)

Where the quantities originally contemplated are so changed that application of the agreed unit price to the quantity of work performed is shown to create a hardship to the Owner or the Contractor, there shall be an equitable adjustment of the Contract to prevent such hardship.

Article 4. Progress Payments—The Owner shall make payments on account of the Contract as provided therein, as follows:
On or about the ____________ day of each month ____________ per cent of the value, based on the Contract prices, of labor and materials incorporated in the work and of materials suitably stored at the site thereof up to the ________ day of that month, as estimated by the Engineer, less the aggregate of previous payments; and upon substantial completion of the entire work, a sum sufficient to increase the total payments to ____________ per cent of the contract price ____________________

____
(Insert here any provision made for limiting or reducing the amount retained after the work reaches a certain stage of completion)

Article 5. Acceptance and Final Payment—Upon receipt of written notice that the work is ready for final inspection and acceptance, the Engineer shall promptly make such inspection, and when he finds the work acceptable under the Contract and the Contract fully performed he shall promptly issue a final certificate, over his own signature, stating that the work provided for in this Contract has been completed and is accepted by him under the terms and conditions thereof, and the entire balance found to be due the Contractor, including the retained percentage, shall be paid to the Contractor at the office of the Owner within ____________________ days after the date of said final certificate.

Before issuance of final certificate the Contractor shall submit evidence satisfactory to the Engineer that all payrolls, material bills, and other indebtedness connected with the work have been paid.

The making and acceptance of the final payment shall constitute a waiver of all claims by the Owner, other than those arising from unsettled liens, from faulty work appearing after final payment or from requirement of the Specifications, and of all claims by the Contractor, except those previously made and still unsettled.

If after the work has been substantially completed, full completion thereof is materially delayed through no fault of the Contractor, and the Engineer so certifies, the Owner shall, upon certificate of the Engineer, and without terminating the Contract, make payment of the balance due for that portion of the work fully completed and accepted. Such payment shall be made under the terms and conditions governing final payment, except that it shall not constitute a waiver of claims.

Article 6. The Contract Documents—The General Conditions of the Contract, the Specifications and the Drawings, together with this Agreement, form the Contract, and they are as fully a part of the Contract as if hereto attached or herein repeated. The following is an enumeration of the Specifications and Drawings.

IN WITNESS WHEREOF the parties hereto have executed this Agreement, the day and year first above written.

Note: This form of A.I.A. Agreement is included as a sample of a fee-basis contract showing reimbursables. *The user of this form should edit all references to agree with "General Conditions" published in this volume rather than to agree with A.I.A. General Conditions.*
The American Institute of Architects has granted the author permission to reprint this form without endorsing or approving the remainder of this volume. Additional copies of this form may be obtained by writing to The American Institute of Architects, 1741 New York Avenue, N.W., Washington 6, D. C.

A FORM OF
AGREEMENT BETWEEN CONTRACTOR AND OWNER

ISSUED BY THE AMERICAN INSTITUTE OF ARCHITECTS FOR USE WHEN THE COST OF THE WORK PLUS A FEE FORMS THE BASIS OF PAYMENT.

THIS AGREEMENT made the ____________________ day of ____________________ in the year nineteen hundred and ______________ by and between ____________________ hereinafter called the Contractor, and ____________________

____

____________________ hereinafter called the Owner, WITNESSETH, that whereas the Owner intends to erect ____________________

____

____

NOW, THEREFORE, the Contractor and the Owner, for the considerations hereinafter named, agree as follows:

Article 1. The Work to be Done and the Documents Forming the Contract.

The Contractor agrees to provide all the labor and materials and to do all things necessary for the proper construction and completion of the work shown and described on Drawings bearing the title ______________ ______________ and numbered ______________ ______________ and in Specifications bearing the same title, the pages of which are numbered ______________

____

The said Drawings and Specifications and the General Conditions of the Contract consisting of Articles numbered one to ____________________ together with this Agreement, constitute the Contract; the Drawings, Specifications and General Conditions being as fully a part thereof and hereof as if hereto attached or herein repeated. If anything in the said General Conditions is inconsistent with this Agreement, the Agreement shall govern.

The said documents have been prepared by ____________________

____

therein and hereinafter called the Architect.

Article 2. Changes in the Work.

The Owner, through the Architect, may from time to time, by written instructions or drawings issued to the Contractor, make changes in the above-named Drawings and Specifications, issue additional instructions, require additional work or direct the omission of work previously ordered, and the provisions of this contract shall apply to all such changes, modifications and additions with the same effect as if they were embodied in the original Drawings and Specifications. Since the cost of all such changes is to merge in the final cost of the work, Articles 15 and 16 of the General Conditions of the Contract are annulled, unless elsewhere especially made applicable.

Article 3. The Contractor's Duties and Status.

The Contractor recognizes the relations of trust and confidence established between him and the Owner by this Agreement. He covenants with the Owner to furnish his best skill and judgment and to cooperate with the Architect in forwarding the interests of the Owner. He agrees to furnish efficient business administration and superintendence and to use every effort to keep upon the work at all times an adequate supply of workmen and materials, and to secure its execution in the best and soundest way and in the most expeditious and economical manner consistent with the interests of the Owner.

Article 4. Fee for Services.

In consideration of the performance of the contract, the Owner agrees to pay the Contractor, in current funds,

as compensation for his services hereunder ______________________________

______________ ($______________) which shall be paid as follows: ______________________

____

Article 5. Costs to be Reimbursed.

The Owner agrees to reimburse the Contractor in current funds all costs necessarily incurred for the proper prosecution of the work and paid directly by the Contractor, such costs to include the following items, and to be at rates not higher than the standard paid in the locality of the work except with prior consent of the Owner:

(*a*) All labor directly on the Contractor's pay roll.

(*b*) Salaries of Contractor's Employees stationed at the field office, in whatever capacity employed. Employees engaged, at shops or on the road, in expediting the production or transportation of material, shall be considered as stationed at the field office and their salaries paid for such part of their time as is employed on this work.

(*c*) The proportion of transportation, traveling and hotel expenses of the Contractor or of his officers or employees incurred in discharge of duties connected with this work.

(*d*) All expenses incurred for transportation to and from the work of the force required for its prosecution.

(*e*) Permit fees, royalties, damages for infringement of patents, and costs of defending suits therefor and for deposits lost for causes other than the Contractor's negligence.

(*f*) Losses and expenses, not compensated by insurance or otherwise, sustained by the Contractor in connection with the work, provided they have resulted from causes other than the fault or neglect of the Contractor. Such losses shall include settlements made with the written consent and approval of the Owner. No such losses and expenses shall be included in the cost of the work for the purpose of determining the Contractor's fee, but if, after a loss from fire, flood or similar cause not due to the fault or neglect of the Contractor, he be put in charge of reconstruction, he shall be paid for his services a fee proportionate to that named in Article 4 hereof.

(*g*) Minor expenses, such as telegrams, telephone service, expressage, and similar petty cash items.

(*h*) Cost of hand tools, not owned by the workmen, canvas and tarpaulins, consumed in the prosecution of the work, and depreciation on such tools, canvas and tarpaulins used but not consumed and which shall remain the property of the Contractor.

Article 6. Costs Not to be Reimbursed.

Reimbursement of expenses to the Contractor shall not include any of the following:

(*a*) Salary of the Contractor, if an individual, or salary of any member of the Contractor, if a firm, or salary of any officer of the Contractor, if a corporation.

(*b*) Salary of any person employed, during the execution of the work, in the main office or in any regularly established branch office of the Contractor.

(*c*) Overhead or general expenses of any kind, except as these may be expressly included in Article 5.

(*d*) Interest on capital employed either in plant or in expenditures on the work, except as may be expressly included in Article 5.

____

____

____

Article 7. Costs to be Paid Direct by the Owner.

In addition to items of cost noted in Article 5 for which the Owner reimburses the Contractor, the Owner shall pay all costs as follows:

(*a*) Materials, supplies, equipment and transportation required for the proper execution of the work, which shall include all temporary structures and their maintenance; all such costs to be at rates not higher than the standard paid in the locality of the work except with prior consent of the Owner.

(*b*) The amounts of all separate contracts.

(*c*) Premiums on all bonds and insurance policies called for under Articles 27, 28, 29 and 30 of the General Conditions of the Contract.

(*d*) Rentals of all construction plant or parts thereof, whether rented from the Contractor or others, in accordance with rental agreements approved by the Architect. Transportation of said construction plant, costs of loading and unloading, cost of installation, dismantling and removal thereof and minor repairs and replacements during its use on the work,—all in accordance with the terms of the said rental agreements.

Article 8. Discounts, Rebates, Refunds.

All discounts, rebates and refunds, and all returns from sale of surplus materials, equipment, etc., shall accrue to the Owner, and the Contractor shall make provisions so that they can be secured.

Article 9. Contractor's Financial Responsibility.

Any cost due to the negligence of the Contractor or anyone directly employed by him, either for the making good of defective work, disposal of material wrongly supplied, making good of damage to property, or excess costs for material or labor, or otherwise, shall be borne by the Contractor, and the Owner may withhold money due the Contractor to cover any such cost already paid by him as part of the cost of the work.

This article supersedes the provisions of Articles 13, 19 and 20 of the General Conditions of the Contract so far as they are inconsistent herewith.

Article 10. Separate Contracts.

All portions of the work that the Contractor's organization has not been accustomed to perform or that the Owner may direct, shall be executed under separate contracts let by the Owner direct. In such cases either the Contractor shall ask for bids from contractors approved by the Architect and shall deliver such bids to him, or the Architect shall procure such bids himself, and in either case the Architect shall determine, with the advice of the Contractor and subject to the approval of the Owner, the award and amount of the accepted bid. The Owner shall contract for such work direct with such approved bidders in accordance with the terms of this agreement and the General Conditions of the Contract, which Conditions shall, for the purposes of such contracts, stand as printed or written and not be subject to the modifications set forth herein.

The Contractor, being fully responsible for the general management of the building operation, shall have full directing authority over the execution of the separate contracts.

The separate Contractors shall not only cooperate with each other, as provided in Article 35 of the General Conditions of the Contract, but they shall conform to all directions of the Contractor in regard to the progress of the work.

Article 11. Title to the Work.

The title of all work completed and in course of construction and of all materials on account of which any payment has been made, and materials to be paid for under Article 7, shall be in the Owner.

Article 12. Accounting, Inspection, Audit.

The Contractor shall check all material and labor entering into the work and shall keep such full and detailed accounts as may be necessary to proper financial management under this Agreement and the system shall be such as is satisfactory to the Architect or to an auditor appointed by the Owner. The Architect, the auditor and their timekeepers and clerks shall be afforded access to the work and to all the Contractor's books, records, correspondence, instructions, drawings, receipts, vouchers, memoranda, etc., relating to this contract, and the Contractor shall preserve all such records for a period of two years after the final payment hereunder.

Article 13. Applications for Payment.

The Contractor shall, between the first and seventh of each month, deliver to the Architect a statement, sworn to if required, showing in detail and as completely as possible all moneys paid out by him on account of the cost of the work during the previous month for which he is to be reimbursed under Article 5 hereof, with original pay rolls for labor, checked and approved by a person satisfactory to the Architect, and all receipted bills.

He shall at the same time submit to the Architect a complete statement of all moneys properly due for materials or on account of separate contracts, or on account of his fee, or otherwise, which are to be paid direct by the Owner under Article 7 hereof.

The provisions of this Article supersede those of Article 24 of the General Conditions of the Contract.

Article 14. Certificates of Payment.

The Architect shall check the Contractor's statements of moneys due, called for in Article 13, and shall promptly issue certificates to the Owner for all such as he approves, which certificates shall be payable on issuance.

The provisions of this Article supersede the first paragraph of Article 25 of the General Conditions of the Contract.

Article 15. Disbursements.

Should the Contractor neglect or refuse to pay, within five days after it falls due, any bill legitimately incurred by him hereunder (and for which he is to be reimbursed under Article 5) the Owner, after giving the Contractor twenty-four hours' written notice of his intention so to do, shall have the right to pay such bill directly, in which event such payment shall not, for the purpose either of reimbursement or of calculating the Contractor's fee, be included in the cost of the work.

Article 16. Termination of Contract.

(*The provisions of this Article supersede all of Article 22 of the General Conditions of the Contract except the first sentence.*)

If the Owner should terminate the contract under the first sentence of Article 22 of the General Conditions of the Contract, he shall reimburse the Contractor for the balance of all payments made by him under Article 5, plus a fee computed upon the cost of the work to date at the rate of percentage named in Article 4 hereof, or if the Contractor's fee be stated as a fixed sum, the Owner shall pay the Contractor such an amount as will increase the payments on account of his fee to a sum which bears the same ratio to the said fixed sum as the cost of the work at the time of termination bears to a reasonable estimated cost of the work completed, and the Owner shall also pay to the Contractor fair compensation, either by purchase or rental, at the election of the Owner, for any equipment retained.

In case of such termination of the contract the Owner shall further assume and become liable for all obligations, commitments and unliquidated claims that the Contractor may have theretofore, in good faith, undertaken or incurred in connection with said work and the Contractor shall, as a condition of receiving the payments mentioned in this Article, execute and deliver all such papers and take all such steps, including the legal assignment of his contractual rights, as the Owner may require for the purpose of fully vesting in him the rights and benefits of the Contractor under such obligations or commitments.

The Contractor and the Owner for themselves, their successors, executors, administrators and assigns hereby agree to the full performance of the covenants herein contained.

IN WITNESS WHEREOF they have executed this agreement the day and year first above written.

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STANDARD GENERAL CONDITIONS FOR ENGINEERING CONSTRUCTION

(Not designed for use in Building Construction)

INDEX TO THE ARTICLES OF THE GENERAL CONDITIONS

Art. 1. Definitions.

(a) The Contract Documents consist of the Agreement, the General Conditions of the Contract, the Drawings and Specifications, including all modifications thereof incorporated in the documents before their execution. These form the Contract.

(b) The Owner, the Contractor and the Engineer are those mentioned as such in the Agreement. They are treated throughout the Contract Documents as if each were of the singular number and masculine gender.

(c) Wherever in this Contract the word Engineer is used it shall be understood as referring to the Engineer of the Owner, acting personally or through an assistant duly authorized in writing for such act by the Engineer.

(d) Written notice shall be deemed to have been duly served if delivered in person to the individual or to a member of the firm or to an officer of the corporation for whom it is intended, or if delivered at or sent by registered mail to the last business address known to him who gives the notice.

(e) The term Subcontractor, as employed herein, includes only those having a direct contract with the Contractor and it includes one who furnishes material worked to a special design according to the plans or specifications of this work, but does not include one who merely furnishes material not so worked.

(f) The term "work" of the Contractor or Subcontractor includes labor or materials or both, equipment, transportation, or other facilities necessary to complete the Contract.

(g) All time limits stated in the Contract Documents are of the essence of the Contract.

Art. 2. Execution, Correlation and Intent of Documents.—The Contract Documents shall be signed in duplicate by the Owner and the Contractor. In case the Owner and the Contractor fail to sign the General Conditions, Drawings or Specifications, the Engineer shall identify them.

The Contract Documents are complementary, and what is called for by any one shall be as binding as if called for by all. The intention of the documents is to include all labor and materials, equipment and transportation necessary for the proper execution of the work. It is not intended, however, that materials or work not covered by or properly inferable from any heading, branch, class or trade of the specifications shall be supplied unless distinctly so noted on the drawings. Materials or work described in words which so applied have a well-known technical or trade meaning shall be held to refer to such recognized standards.

Art. 3. Detail Drawings and Instructions.—The Engineer shall furnish with reasonable promptness, additional instructions, by means of drawings or otherwise, necessary for the proper execution of the work. All such drawings and instructions shall be consistent with the Contract Documents, true developments thereof, and reasonably inferable therefrom.

Art. 4. Copies of Drawings Furnished.—Unless otherwise provided in the Contract Documents the Engineer will furnish to the Contractor, free of charge, all copies of drawings and specifications reasonably necessary for the execution of the work.

Art. 5. Order of Completion.—The Contractor shall submit at such times as may be requested by the Engineer, schedules which shall show the order in which the Contractor proposes to carry on the work with dates at which the Contractor will start the several parts of the work and estimated dates of completion of the several parts.

Art. 6. Drawings and Specifications on the Work.—The Contractor shall keep one copy of all drawings and specifications on the work, in good order, available to the Engineer and to his representatives.

Art. 7. Ownership of Drawings.—All drawings, specifications and copies thereof furnished by the Engineer are his property. They are not to be used on other work and, with the exception of the signed Contract set, are to be returned to him on request, at the completion of the work. All models are the property of the Owner.

Art. 8. Contractor's Understanding.—It is understood and agreed that the Contractor has, by careful examination, satisfied himself as to the nature and location of the work, the conformation of the ground, the character, quality and quantity of the materials to be encountered, the character of equipment and facilities needed preliminary to and during the prosecution of the work, the general and local conditions, and all other matters which can in any way affect the work under this Contract. No verbal agreement or conversation with any officer, agent or employe of the Owner, either before or after the execution of this contract, shall affect or modify any of the terms or obligations herein contained.

Art. 9. Materials, Appliances, Employes.—Unless otherwise stipulated, the Contractor shall provide and pay for all materials, labor, water, tools, equipment, light, power, transportation and other facilities necessary for the execution and completion of the work.

Unless otherwise specified, all materials shall be new and both workmanship and materials shall be of a good quality. The Contractor shall, if required, furnish satisfactory evidence as to the kind and quality of materials.

The Contractor shall at all times enforce strict discipline and good order among his employes, and shall not employ on the work any unfit person or any one not skilled in the work assigned to him.

Art. 10. Royalties and Patents.—The Contractor shall pay all royalties and license fees. He shall defend all suits or claims for infringement of any patent rights and shall save the Owner harmless from loss on account thereof, except that the Owner shall be responsible for all such loss when a particular process or the product of a particular manufacturer or manufacturers is specified, but if the Contractor has information that the process or article specified is an infringement of a patent he shall be responsible for such loss unless he promptly gives such information to the Engineer.

Art. 11. Surveys, Permits and Regulations.—The Owner shall furnish all surveys unless otherwise specified. Permits and licenses of a temporary nature necessary for the prosecution of the work shall be secured and paid for by the Contractor. Permits, licenses and easements for permanent structures or permanent changes in existing facilities shall be secured and paid for by the Owner, unless otherwise specified.

The Contractor shall give all notices and comply with all laws, ordinances, rules and regulations bearing on the conduct of the work as drawn and specified. If the Contractor observes that the drawings and specifications are at

variance therewith, he shall promptly notify the Engineer in writing, and any necessary changes shall be adjusted as provided in the Contract for changes in the work. If the Contractor performs any work knowing it to be contrary to such laws, ordinances, rules and regulations, and without such notice to the Engineer, he shall bear all costs arising therefrom.

Art. 12. Protection of Work and Property.—The Contractor shall continuously maintain adequate protection of all his work from damage and shall protect the Owner's property from injury or loss arising in connection with this Contract. He shall make good any such damage, injury or loss, except such as may be directly due to errors in the Contract Documents or caused by agents or employes of the Owner. He shall adequately protect adjacent property as provided by law and the Contract Documents. He shall provide and maintain all passage ways, guard fences, lights and other facilities for protection required by public authority or local conditions.

In an emergency affecting the safety of life or of the work or of adjoining property, the Contractor, without special instruction or authorization from the Engineer, is hereby permitted to act, at his discretion, to prevent such threatened loss or injury, and he shall so act, without appeal, if so instructed or authorized. Any compensation, claimed by the Contractor on account of emergency work, shall be determined by agreement or arbitration.

Art. 13. Inspection of Work.—The Engineer and his representatives shall at all times have access to the work wherever it is in preparation or progress and the Contractor shall provide proper facilities for such access and for inspection.

If the specifications, the Engineer's instructions, laws, ordinances or any public authority require any work to be specially tested or approved, the Contractor shall give the Engineer timely notice of its readiness for inspection, and if the inspection is by another authority than the Engineer, of the date fixed for such inspection. Inspections by the Engineer shall be promptly made, and where practicable at the source of supply. If any work should be covered up without approval or consent of the Engineer, it must, if required by the Engineer, be uncovered for examination at the Contractor's expense.

Re-examination of questioned work may be ordered by the Engineer and if so ordered the work must be uncovered by the Contractor. If such work be found in accordance with the Contract Documents the Owner shall pay the cost of re-examination and replacement. If such work be found not in accordance with the Contract Documents the Contractor shall pay such cost, unless he shall show that the defect in the work was caused by another Contractor, and in that event the Owner shall pay such cost.

Art. 14. Superintendence: Supervision.—The Contractor shall keep on his work during its progress a competent superintendent and any necessary assistants, all satisfactory to the Engineer. The superintendent shall not be changed except with the consent of the Engineer, unless the superintendent proves to be unsatisfactory to the Contractor and ceases to be in his employ. The superintendent shall represent the Contractor in his absence and all directions given to him shall be as binding as if given to the Contractor. Important directions shall be confirmed in writing to the Contractor. Other directions shall be so confirmed on written request in each case. The Contractor shall give efficient supervision to the work, using his best skill and attention.

If the Contractor, in the course of the work, finds any discrepancy between the drawings and the physical conditions of the locality, or any errors or omissions in drawings or in the layout as given by points and instructions, it shall be his duty to immediately inform the Engineer, in writing, and the Engineer shall promptly verify the same. Any work done after such discovery, until authorized, will be done at the Contractor's risk.

Neither party shall employ or hire any employe of the other party without his consent.

Art. 15. Changes in the Work.—The Owner, without invalidating the Contract, may order extra work or make changes by altering, adding to or deducting from the work, the Contract Sum being adjusted accordingly. All such work shall be executed under the conditions of the original Contract except that any claim for extension of time caused thereby shall be adjusted at the time of ordering such change.

In giving instructions, the Engineer shall have authority to make minor changes in the work, not involving extra cost, and not inconsistent with the purposes of the work, but otherwise, except in an emergency endangering life or property, no extra work or change shall be made unless in pursuance of a written order by the Engineer, and no claim for an addition to the Contract Sum shall be valid unless so ordered.

The value of any such extra work or change shall be determined in one or more of the following ways:

(a) By estimate and acceptance in a lump sum.
(b) By unit prices named in the Contract or subsequently agreed upon.
(c) By cost and percentage or by cost and a fixed fee.

If none of the above methods is agreed upon, the Contractor, provided he receives an order as above, shall proceed with the work. In such case and also under case (c), he shall keep and present in such form as the Engineer may direct, a correct account of the net cost of labor and materials, together with vouchers. In any case, the Engineer shall certify to the amount, including reasonable allowance for overhead and profit, due to the Contractor. Pending final determination of value, payments on account of changes shall be made on the Engineer's estimate.

Art. 16. Claims for Extra Cost.—If the Contractor claims that any instructions by drawings or otherwise involve extra cost under this Contract, he shall give the Engineer written notice thereof within a reasonable time after the receipt of such instructions, and in any event before proceeding to execute the work, except in emergency endangering life or property, and the procedure shall then be as provided for changes in the work. No such claim shall be valid unless so made.

Art. 17. Deductions for Uncorrected Work.—If the Engineer deems it inexpedient to correct work injured or done not in accordance with the Contract, an equitable deduction from the Contract price shall be made therefor.

Art. 18. Delays and Extension of Time.—If the Contractor be delayed at any time in the progress of the work by any act or neglect of the Owner or of his employes, or by any other Contractor employed by the Owner, or by changes ordered in the work, or by strikes, lockouts, fire, unusual delay in transportation, unavoidable casualties or any causes beyond the Contractor's control, or by delay authorized by the Engineer pending arbitration, or by any cause which the Engineer shall decide to justify the delay, then the time of completion shall be extended for such reasonable time as the Engineer may decide.

No such extension shall be made for delay occurring more than seven days before claim therefor is made in writing to the Engineer. In the case of a continuing cause of delay only one claim is necessary.

If no schedule or agreement stating the dates upon which drawings shall be furnished is made then no claim for delay shall be allowed on account of failure to furnish drawings until two weeks after demand for such drawings and not then unless such claim be reasonable.

This article does not exclude the recovery of damages for delay by either party under other provisions in the Contract Documents.

Art. 19. Correction of Work Before Final Payment.—The Contractor shall promptly remove from the premises all materials condemned by the Engineer as failing to conform to the Contract, whether incorporated in the work or not, and the Contractor shall promptly replace and re-execute his own work in accordance with the Contract and without expense to the Owner and shall bear the expense of making good all work of other contractors destroyed or damaged by such removal or replacement.

If the Contractor does not remove such condemned work and materials within a reasonable time, fixed by written notice, the Owner may remove them and may store the material at the expense of the Contractor. If the Contractor does not pay the expense of such removal within ten days' time thereafter, the Owner may, upon ten days' written notice, sell such materials at auction or at private sale and shall account for the net proceeds thereof, after deducting all the costs and expenses that should have been borne by the Contractor.

Art. 20. Suspension of Work.—The Owner may at any time suspend the work, or any part thereof by giving days' notice to the Contractor in writing. The work shall be resumed by the Contractor within ten (10) days after the date fixed in the written notice from the Owner to the Contractor so to do. The Owner shall reimburse the Contractor for expense incurred by the Contractor in connection with the work under this Contract as a result of such suspension.

But if the work or any part thereof shall be stopped by the notice in writing aforesaid, and if the Owner does not give notice in writing to the Contractor to resume work at a date within of the date fixed in the written notice to suspend, then the Contractor may abandon that portion of the work so suspended and he will be entitled to the estimates and payments for all work done on the portions so abandoned, if any.

Art. 21. The Owner's Right to Do Work.—If the Contractor should neglect to prosecute the work properly or fail to perform any provision of this Contract, the Owner, after three days' written notice to the Contractor, may, without prejudice to any other remedy he may have, make good such deficiencies and may deduct the cost thereof from the payment then or thereafter due the Contractor.

Art. 22. The Owner's Right to Terminate Contract.—If the Contractor should be adjudged a bankrupt, or if he should make a general assignment for the benefit of his creditors, or if a receiver should be appointed on account of his insolvency, or if he should persistently or repeatedly refuse or should fail, except in cases for which extension of

time is provided, to supply enough properly skilled workmen or proper materials, or if he should fail to make prompt payment to subcontractors or for material or labor, or persistently disregard laws, ordinances or the instructions of the Engineer, or otherwise be guilty of a substantial violation of any provision of the contract, then the Owner, upon the certificate of the Engineer that sufficient cause exists to justify such action, may, without prejudice to any other right or remedy and after giving the Contractor seven days' written notice, terminate the employment of the Contractor and take possession of the premises and of all materials, tools and appliances thereon and finish the work by whatever method he may deem expedient. In such case the Contractor shall not be entitled to receive any further payment until the work is finished. If the unpaid balance of the contract price shall exceed the expense of finishing the work, including compensation for additional managerial and administrative services, such excess shall be paid to the Contractor. If such expense shall exceed such unpaid balance, the Contractor shall pay the difference to the Owner. The expense incurred by the Owner as herein provided, and the damage incurred through the Contractor's default, shall be certified by the Engineer.

Art. 23. Contractor's Right to Stop Work or Terminate Contract.—If the work should be stopped under an order of any court, or other public authority, for a period of three months, through no act or fault of the Contractor or of anyone employed by him, or if the Engineer should fail to issue any estimate for payment within seven days after it is due, or if the Owner should fail to pay the Contractor within seven days of its maturity and presentation, any sum certified by the Engineer or awarded by arbitrators, then the Contractor may, upon seven days' written notice to the Owner and the Engineer, stop work or terminate this Contract and recover from the Owner payment for all work executed and any loss sustained upon any plant or materials and reasonable profit and damages.

Art. 24. Removal of Equipment.—In the case of annulment of this Contract before completion from any cause whatever, the Contractor, if notified to do so by the Owner, shall promptly remove any part or all of his equipment and supplies from the property of the Owner, failing which the Owner shall have the right to remove such equipment and supplies at the expense of the Contractor.

Art. 25. Use of Completed Portions.—The Owner shall have the right to take possession of and use any completed or partially completed portions of the work, notwithstanding the time for completing the entire work or such portions may not have expired but such taking possession and use shall not be deemed an acceptance of any work not completed in accordance with the Contract Documents. If such prior use increases the cost of or delays the work, the Contractor shall be entitled to such extra compensation, or extension of time, or both, as the Engineer may determine.

Art. 26. Payments Withheld.—The Owner may withhold or, on account of subsequently discovered evidence, nullify the whole or a part of any certificate to such extent as may be necessary to protect himself from loss on account of:

(a) Defective work not remedied.
(b) Claims filed or reasonable evidence indicating probable filing of claims.
(c) Failure of the Contractor to make payments properly to subcontractors or for material or labor.
(d) A reasonable doubt that the Contract can be completed for the balance then unpaid.
(e) Damage to another Contractor.

When the above grounds are removed payment shall be made for amounts withheld because of them.

Art. 27. Contractor's Liability Insurance.—The Contractor shall maintain such insurance as will protect him from claims under workmen's compensation acts and from any other claims for damages for personal injury, including death, which may arise from operations under this Contract, whether such operations be by himself or by any subcontractor or anyone directly or indirectly employed by either of them. Certificates of such insurance shall be filed with the Engineer, if he so require, and shall be subject to his approval for adequacy of protection.

Art. 28. Indemnity.—The Contractor shall indemnify and save harmless the Owner from and against all losses and all claims, demands, payments, suits, actions, recoveries and judgments of every nature and description brought or recovered against him, by reason of any act or omission of the said Contractor, his agents or employes, in the execution of the work or in the guarding of it.

The Contractor shall, and is hereby authorized to, maintain and pay for such insurance, issued in the name of the Owner, as will protect the Owner from his contingent liability under this Contract, and the Owner's right to enforce against the Contractor any provision of this article shall be contingent upon the full compliance by the Owner with the terms of such insurance policy or policies, a copy of which shall be deposited with the Owner.

Art. 29. Fire Insurance.—The Contractor shall secure, in the name of the Owner, policies of fire insurance in amount, form and companies satisfactory to the Engineer, upon such structures and material as shall be specified by the latter, payable to the Owner for the benefit of the Contractor or the Owner as the Engineer shall find their interests to appear.

Art. 30. Guaranty Bonds.—The Owner shall have the right, prior to the signing of the Contract, to require the Contractor to furnish bond covering the faithful performance of the Contract and the payment of all obligations arising thereunder, in such form as the Owner may prescribe and with such sureties as he may approve. If such bond is required by instructions given previous to the receipt of bids, the premium shall be paid by the Contractor; if subsequent thereto, it shall be paid by the Owner.

Art. 31. Damages.—Any claim for damage arising under this Contract shall be made in writing to the party liable within a reasonable time of the first observance of such damage and not later than the time of final payment, except as expressly stipulated otherwise in the case of faulty work or materials, and shall be adjusted by agreement or arbitration.

Art. 32. Liens.—Neither the final payment nor any part of the retained percentage shall become due until the Contractor, if required, shall deliver to the Owner a complete release of all liens arising out of this Contract, or receipts in full in lieu thereof and, if required in either case, an affidavit that so far as he has knowledge or information the releases and receipts include all the labor and material for which a lien could be filed; but the Contractor may, if any subcontractor refuses to furnish a release or receipt in full, furnish a bond satisfactory to the Engineer, to indemnify the Owner against any lien. If any lien remains unsatisfied after all payments are made, the Contractor shall refund to the Owner all moneys that the latter may be compelled to pay in discharging such a lien, including all costs and a reasonable attorney's fee.

Art. 33. Assignment.—Neither party to the Contract shall assign the Contract or sublet it as a whole without the written consent of the other, nor shall the Contractor assign any moneys due or to become due to him hereunder, without the previous written consent of the Engineer.

Art. 34. Rights of Various Interests.—Wherever work being done by the Owner's forces or by other contractors is contiguous to work covered by this Contract the respective rights of the various interests involved shall be established by the Engineer, to secure the completion of the various portions of the work in general harmony.

Art. 35. Separate Contracts.—The Owner reserves the right to let other contracts in connection with this work. The Contractor shall afford other contractors reasonable opportunity for the introduction and storage of their materials and the execution of their work, and shall properly connect and coordinate his work with theirs.

If any part of the Contractor's work depends for proper execution or results upon the work of any other contractor, the Contractor shall inspect and promptly report to the Engineer any defects in such work that render it unsuitable for such proper execution and results. His failure so to inspect and report shall constitute an acceptance of the other contractor's work as fit and proper for the reception of his work, except as to defects which may develop in the other contractor's work after the execution of his work.

To insure the proper execution of his subsequent work the Contractor shall measure work already in place and shall at once report to the Engineer any discrepancy between the executed work and the drawings.

Art. 36. Subcontracts.—The Contractor shall, as soon as practicable after the signature of the Contract, notify the Engineer in writing of the names of subcontractors proposed for the work and shall not employ any that the Engineer may within a reasonable time object to as incompetent or unfit.

The Contractor agrees that he is as fully responsible to the Owner for the acts and omissions of his subcontractors and of persons either directly or indirectly employed by them, as he is for the acts and omissions of persons directly employed by him.

Nothing contained in the Contract Documents shall create any contractural relation between any subcontractor and the Owner.

Art. 37. Points and Instructions.—The Contractor shall provide reasonable and necessary opportunities and facilities for setting points and making measurements. He shall not proceed until he has made timely demand upon the Engineer for, and has received from him, such points and instructions as may be necessary as the work progresses. The work shall be done in strict conformity with such points and instructions.

The Contractor shall carefully preserve bench marks, reference points and stakes, and in case of willful or careless destruction, he shall be charged with the resulting expense and shall be responsible for any mistakes that may be caused by their unnecessary loss or disturbance.

Art. 38. Engineer's Status.—The Engineer shall have general supervision and direction of the work. He has authority to stop the work whenever such stoppage may be necessary to insure the proper execution of the Contract. He shall also have authority to reject all work and materials which do not conform to the Contract, to direct the application of forces to any portion of the work, as in his judgment is required, and to order the force increased or diminished, and to decide questions which arise in the execution of the work.

Art. 39. Engineer's Decisions.—The Engineer shall, within a reasonable time after their presentation to him, make decisions in writing on all claims of the Owner or the Contractor and on all other matters relating to the execution and progress of the work or the interpretation of the Contract Documents.

All such decisions of the Engineer shall be final except in cases where time and/or financial considerations are involved, which, if no agreement in regard thereto is reached, shall be subject to arbitration.

Art. 40. Arbitration.—(a) Demand for Arbitration.—Any decision of the Engineer which is subject to arbitration shall be submitted to arbitration upon the demand of either party to the dispute.

The Contractor shall not cause a delay of the work because of the pendency of arbitration proceedings, except with the written permission of the Engineer, and then only until the arbitrators shall have an opportunity to determine whether or not the work shall continue until they decide the matters in dispute.

The demand for arbitration shall be delivered in writing to the Engineer and the adverse party, either personally or by registered mail to the last known address of each, within ten days of the receipt of the Engineer's decision, and in no case after final payment has been accepted except as otherwise expressly stipulated in the Contract Documents. If the Engineer fails to make a decision within a reasonable time, a demand for arbitration may be made as if his decision had been rendered against the demanding party.

(b) Arbitrators.—No one shall be nominated or act as an arbitrator who is in any way financially interested in this Contract or in the business affairs of the owner, or the Contractor, or the Engineer, or otherwise connected with any of them. Each arbitrator shall be a person in general familiar with the work or the problem involved in the dispute submitted to arbitration.

Unless otherwise provided by controlling statutes, the parties may agree upon one arbitrator; otherwise there shall be three, one named in writing, by each party to this Contract, to the other party, and the third chosen by those two arbitrators, or if they should fail to select a third within fifteen days, then he shall be appointed by the presiding officer, if a disinterested party, of the Bar Association nearest to the location of the work.* Should the party demanding arbitration fail to name an arbitrator within ten days of his demand, his right to arbitration shall lapse. Should the other party fail to name an arbitrator within said ten days, then said * presiding officer shall appoint such arbitrator within ten days, and upon his failure so to do then such arbitrator shall be appointed on the petition of the party demanding arbitration by a judge of the Federal Court in the district where such arbitration is to be held.

The said * presiding officer shall have the power to declare the position of any arbitrator vacant by reason of refusal or inability to act, sickness, death, resignation, absence or neglect. Any vacancy shall be filled by the party making the original appointment, and unless so filled within five days after the same has been declared, it shall be filled by the said * presiding officer. If testimony has been taken before a vacancy has been filled, the matter must be reheard unless a rehearing is waived in the submission or by the written consent of the parties.

If there be one arbitrator his decision shall be binding; if three, the decision of any two shall be binding in respect to both the matters submitted to and the procedure followed during the arbitration. Such decision shall be a condition precedent to any right of legal action.

(c) Arbitration Procedure.—The arbitrators shall deliver a written notice to each of the parties and to the Engineer, either personally or by registered mail to the last known address of each, of the time and place for the beginning of the hearing of the matters submitted to them. Each party may submit to the arbitrators such evidence and argument as he may desire and the arbitrators may consider pertinent. The arbitrators shall, however, be the judges of all matters of law and fact relating to both the subject matters of and the procedure during arbitration and shall not be bound by technical rules of law or procedure. They may hear evidence in whatever form they desire. The parties may be represented before them by such person as each may select, subject to the disciplinary power of the arbitrators if such representative shall interfere with the orderly or speedy conduct of the proceedings.

Each party and the Engineer shall supply the arbitrators with such papers and information as they may demand, or with any witness whose movements are subject to their respective control, and upon refusal or neglect to comply

* To provide some other agency for appointing arbitrators strike out reference to presiding officer of the Bar Association and insert desired designation. In the vicinity of New York, the Arbitration Society of America, Inc., and the Chamber of Commerce of the State of New York have Arbitration Committees which often act in this capacity.

with such demands the arbitrators may render their decision without the evidence which might have been elicited therefrom, and the absence of such evidence shall afford no ground for challenge of the award by the party refusing or neglecting to comply with such demand.

The submission to arbitration (the statement of the matters in dispute between the parties to be passed upon by the arbitrators) shall be in writing duly acknowledged before a notary. Unless waived in writing by both parties to the arbitration, the arbitrators, before hearing testimony, shall be sworn by an officer authorized by law to administer an oath, faithfully and fairly to hear and examine the matters in controversy and to make a just award according to the best of their understanding.

The arbitrators, if they deem the case demands it, are authorized to award to the party whose contention is sustained such sums as they shall consider proper for the time, expense and trouble incident to the arbitration, and if the arbitration was demanded without reasonable cause, damages for delay and other losses. The arbitrators shall fix their own compensation, unless otherwise provided by agreement, and shall assess the costs and charges of the arbitration upon either or both parties.

The award of the arbitrators shall be in writing and acknowledged like a deed to be recorded, and a duplicate shall be delivered personally or by registered mail, forthwith upon its rendition, to each of the parties to the controversy and to the Engineer. Judgment may be rendered upon the award by the Federal Court or the highest State Court having jurisdiction to render same.

The award of the arbitrators shall not be open to objection on account of the form of the proceedings or the award, unless otherwise provided by the controlling statutes. In the event of such statutes providing on any matter covered by this Article otherwise than as hereinbefore specified, the method of procedure throughout and the legal effect of the award shall be wholly in accord with said statutes, it being the intention hereby to lay down a principle of action to be followed, leaving its local application to be adapted to the legal requirements of the jurisdiction having authority over the arbitration.

The Engineer shall not be deemed a party to the dispute. He is given the right to appear before the arbitrators to explain the basis of his decision and give such evidence as they may require.

Art. 41. Lands for Work.—The Owner shall provide the lands upon which the work under this Contract is to be done, except that the Contractor shall provide land required for the erection of temporary construction facilities and storage of his material, together with right of access to same.

Art. 42. Cleaning Up.—The Contractor shall, as directed by the Engineer, remove from the Owner's property and from all public and private property, at his own expense, all temporary structures, rubbish and waste materials resulting from his operations.

SPECIAL CONDITIONS

INDEX

Article 1. Surveys, Lines, and Grades. The owner will furnish only basic reference lines and bench marks from which the contractor shall establish such other points as he may need, unless otherwise specified,

Or the contractor will make his own surveys and establish his own grades after the engineer furnishes the basic reference lines and bench marks.

On heavy construction work such as railroads, dams, bridges, etc., it is common practice for the engineer to establish all lines and grades. On grading work such as airports and highways, it is advised that the engineer establish reference lines and grade stakes at the beginning of the work and specify that all grade stakes, reference lines, etc., destroyed by the contractor during the progress of his work be replaced at the contractor's expense.

Article 2. Responsibility Regarding Existing Utilities and Structures. The existence and location of underground utilities indicated on the plans are not guaranteed and shall be investigated and verified in the field by the contractor before starting work. Excavation in the vicinity of existing structures and utilities shall be carefully done by hand.

The contractor shall be held responsible for any damage to, and for maintenance and protection of, existing utilities and structures.

Article 3. Tools, Plant, and Equipment. If at any time before the commencement or during the progress of the work, tools, plant, or equipment appear to the engineer to be insufficient, inefficient, or inappropriate to secure the quality of the work required or the proper rate of progress, the engineer may order the contractor to increase their efficiency, to improve their character, to augment their number, or to substitute new tools, plant, or equipment as the case may be, and the contractor must conform to such order; but the failure of the engineer to demand such increase of efficiency, number, or improvement shall not relieve the contractor of his obligation to secure the quality of work and the rate of progress necessary to complete the work within the time required by this contract to the satisfaction of the owner.

Article 4. Accidents. The contractor shall provide, at the site, such equipment and medical facilities as are necessary to supply first-aid service to anyone who may be injured in connection with the work.

The contractor must promptly report in writing to the engineer all accidents whatsoever arising out of, or in connection with, the performance of the work, whether on, or adjacent to, the site, which caused death, personal injury, or property damages, giving full details and statements of witnesses. In addition, if death or serious injuries or serious damages are caused, the accident shall be reported immediately by telephone or messenger to both the engineer and the owner.

If any claim is made by anyone against the contractor or any subcontractor on account of any accident, the contractor shall promptly report the facts in writing to the engineer, giving full details of the claim.

Article 5. Stage Plans. Stage plans of structural alterations, cofferdams, ______, furnished or approved by the engineer, shall be adhered to unless objected to in writing by the contractor, but the submission or approval of such stage plans by the engineer shall not relieve the contractor of full responsibility for the safety of the work.

Article 6. Contractor's Office. The contractor shall provide and locate where directed a temporary, weather-tight job office for his own use complete with facilities for filing, drawings, specifications, correspondence, etc., and

* If used will supersede Art. 11 of "General Conditions."

other appurtenances necessary for the proper operation of the work. Same shall be removed on completion of the work.

Article 7. Field Office for Owner and Engineer. The contractor shall construct at his own expense ____ field office(s) for the owner and engineer.

The office shall be approximately ____ ft. by ____ ft. in size by 8 ft. minimum ceiling height and shall be of weathertight construction. The inside shall be lined with approved lining. The office shall have ____ windows, ____ doors, and a tight floor 8 in. off the ground.

The office shall be supplied with cylinder locks which can be opened by the same key. Six keys shall be furnished.

The office shall be provided with watchman and janitor service; a toilet, sink, running water, and sewer connections; heating equipment; electric wiring and fixtures and telephone service with ____ extensions.

____ ( ) suitable office desk with drawers and locks.
____ ( ) tables (not less than ____ ft. by ____ ft.)
____ ( ) office chairs.
____ ( ) swivel chairs.
____ ( ) supply cabinets with not less than ____ sq. ft. of shelves.
____ ( ) coat racks or closets.
____ ( ) drafting tables ____ ft. by ____ ft. with stools.
____ ( ) lockers, 1 ft. 6 in. by 2 ft. 0 in. by 6 ft. 0 in.
____ ( ) racks to hold plans.
____ ( ) tripod racks for ____ tripods.

The field office shall be built in the location as directed and shall be removed at the conclusion of the work or as directed. The contractor shall submit a sketch of this building for approval.

Article 8. Telephone. The contractor shall provide, pay for, and maintain in the job office a telephone. A coin box telephone shall be installed for the use of the subcontractors.

Article 9. Measurement of Quantities. The quantities of work performed will be computed by the engineer on the basis of measurements taken by the engineer or his assistants, and these measurements shall be final and binding.

All work computed under the contract shall be measured by the engineer according to the United States Standard Measurements and Weights.

Specification should state which items are to be measured along actual or slope surface and which horizontally. State which items are measured according to neat lines, or axially along center line, or any other detailed pertinent requirements.

Article 10. Shop Drawings. *See individual specifications.*

Article 11. Cost Breakdown. The contractor shall within five days after the execution of the contract submit in a form acceptable to the engineer a schedule showing the subdivision of his contract consideration into its various parts, stating quantities and prices, to be made a basis for checking or computing monthly estimates. The prices shall include all costs of each item. No payments will be made to the contractor until such schedule has been submitted to and approved by the engineer.

Article 12. Borings and Subsurface Information Not Guaranteed. Borings and subsurface information shown is for the general information of the bidders and is not guaranteed.

SPECIAL CONDITIONS

CHECK LIST

1. Removal and disposal of existing structures and obstructions.
2. Rights in the use of materials found on the work.
3. Submission of weekly pay rolls and affidavits.

4. Work in freezing weather. *Specify whether: (a) work shall cease; (b) work must continue; (c) work may continue with specified protection.*
5. Protection of trees, plants, and shrubs.
6. Sanitary provisions and facilities, toilets, locker rooms, etc., for construction force.
7. Commissaries, lodging, bunk houses.
8. Watchmen—contractor to furnish, etc.
9. Project signs, warning signs, barricades, emergency lighting, temporary heat.
10. Coordination with others; contract may not be in total possession of site, etc.
11. Field or plant laboratory—contractor to provide.
12. Restoration of site and access.
13. Explosives: use, handling, storage, and transportation.
14. Materials furnished by owner: under what conditions, etc.
15. Federal participation; any special provisions required by participating agency.
16. Freight and waybills—contractor to furnish.
17. Records of materials purchased—contractor to furnish.
18. Property lines and monuments—contractor to protect, reference and reset if disturbed.
19. Disposal of surplus material.
20. Storage of materials.
21. Detours: maintenance of, location, restoration, etc.
22. Shoring or underpinning of adjacent properties.
23. Guaranty against defective work. *List particular bonds required, such as for roofing or waterproofing guarantees.*
24. Fire: fire protection, restrictions, season, etc.
25. This contractor shall cooperate with other contractors. *In this space should be enumerated the other contractors and instructions as to how this contractor will be expected to cooperate with them.*
26. Schedule of minimum wage rates, posting of same, etc.
27. Deductions for Social Security, Workmen's Compensation, unemployment insurance, etc.
28. No deductions from wages except as authorized or required by law.
29. Payment of wages, weekly or otherwise, by cash or by check on solvent bank; arrangements to cash checks.
30. Preference in employment: local residents, citizens, veterans, etc. Employment source: agencies, hiring halls, etc.
31. Qualifications for employment: minors, union labor, convict labor, aliens, etc.
32. Hours of work.
33. Non-discrimination against race, creed, or color.
34. Transportation of employees for isolated work.
35. "Kick-Back" Statute (Copeland Act 48, Statute 948).
36. Access to site, restrictions, restoration.
37. Priorities or preference rating assigned to work—Owner will *or* will not assist in obtaining.
38. Engineer's preliminary cost and quantity estimate, usually included in unit price contracts.
39. Materials: preference shown domestic materials, restrictions on materials manufactured by convict or prison labor, etc.
40. Contractor's use of premises: restrictions, etc.
41. No personal liability of public officials (*for public works*).

II

STRUCTURAL SPECIFICATIONS

PREPARATION OF SITE

I. Scope of Work.

II. Relocation or Demolition of Existing Buildings or Structures.

Specification relative to this type of work must state precisely the nature of the work, safeguards to be observed, the disposition of debris as well as of salvageable material, if any, and such other applicable provisions as apply to the specific project.

III. Clearing and Grubbing.

The area within limits shown on the plans shall be cleared of fences, trees, logs, stumps, brush, vegetation, rubbish, and other perishable or objectionable matter. Stumps and roots between slope stakes in cuts and in embankments 3 ft. or less in depth shall be removed to a depth of 18 in. below subgrade. Outside of slope limits and under embankments more than 3 ft. deep, all trees, stumps, brush, etc., shall be cut off approximately level with surface, except growth designated for preservation.

Spoiled material shall be burned or removed to approved disposal areas. Ashes shall be spread or removed as the engineer may direct.

Specify storage or use of merchantable timber, firewood, etc.

IV. Basis of Payment.

Specify whether unit prices or lump sum apply, and how.

State work included and any that is not required by the contract.

Give method of measurement for unit price contract.

If unit price contract, state approximate quantities for each item to be used for comparison of bids.

If lump sum contract, require submittal of unit prices applicable to any change in contract plan quantities.

BORINGS FOR STRUCTURES

I. Scope of Work.

Work Included. This contract shall include the making of all borings at points shown on plot plans and as specified herein.

Work Not Included. Test pits

II. Workmanship and Methods.

Location of borings shall be approximately as shown on plot plan.

Depth of borings shall be ____ except that boring No. ____ shall be carried down to ____. However, if rock is encountered before reaching either of above depths, core boring shall be made 5 ft. 0 in. into the rock.

Boring through earth shall be made with a $2\frac{1}{2}$-in. extra heavy casing in 5-ft. lengths. Earth shall be removed by jetting or blowing, and dry samples shall be taken by driving sample spoon 1 ft. 0 in. below bottom of casing. If this does not produce sample on account of softness of ground, sample shall be driven deeper and a slotted-hole-type spoon used.

Boring in hard strata or rock shall be made by the chilled shot or diamond drill method. If material is soft rock, a diamond drill equipped with a double core barrel of such construction that the drilling water is fed to the bit without coming in contact with the core shall be used.

III. Samples.

Samples of earth shall be taken every 5 ft. 0 in. and at any point where material changes in character.

Rock cores shall not be less than $1\frac{1}{8}$ in. in diameter.

Samples shall be sealed in watertight containers and shipped to office of the engineer. They shall have labels giving the following information: number of boring, elevations of sample, and material.

IV. Drawings.

The contractor shall furnish a boring plan showing location and numbers of holes, and he shall plot vertical sections showing material encountered referred to datum, number of blows per linear foot, weight of casing, weight of hammer and drop of hammer, and ground-water level for all holes when encountered.

V. Basis of Payment.

The contractor shall be paid according to unit price per linear foot of hole measured from surface of ground to bottom of hole.

The contractor shall state in his bid the following: unit price per linear foot for boring through rock; unit price per linear foot for boring through earth; unit price per linear foot for boring through fill, sand, or other material not rock.

EXCAVATION AND GRADING FOR STRUCTURES

I. Scope of Work.

Work Included. Excavation and grading for structures, pits, trenches, and all work as shown on plans.

Work Not Included. *Specify other sections such as "Preparation of Site," "Excavation, Trenching, Backfilling for Utility Systems," and items included in mechanical specification.*

II. Borings and Exploration Pits.

Boring and subsurface data shown on plans shall be for general information only, and variation therefrom shall not affect the terms of the contract.

III. Stripping of Topsoil, Seeding, Sodding, etc.

Specify as required for job. See applicable portions of specification for "Grading for Roads, Airports, and Railroads."

IV. Excavation.

Excavation Limits for Structures. Excavation and shoring shall be kept within 2 ft. of the neat lines of structure foundations. (*Specify banks to be sloped at a safe angle or shored according to conditions.*)

Excavation below Elevations Shown on the Plan. If filling is not authorized by the engineer, the excavation shall be filled with 1 : 3 : 6 stone concrete by the contractor without cost to the owner.

Drainage of Excavated Areas. Grading in vicinity of structures shall be controlled to prevent surface water running into excavated areas. (*Specify drainage and maintenance as required. Include dewatering and pumping.*)

Protection of Adjacent Buildings and Existing Structures. Excavations shall not be carried below existing building foundations until underpinning and shoring to be performed by others *or* by this contractor (*specify one*) have been completed. All existing structures, pipes, and foundations which are to be incorporated into the final work shall be adequately protected or replaced by the contractor without cost to the owner.

Stockpiles. Excavated material to be used for backfill shall be stockpiled. (*Specify how to stockpile.*)

Waste. Excess material from excavation not suitable or required for backfill or filling shall be wasted. (*Specify how to waste excess material.*)

Rock Excavation. Blasting shall be done in accordance with local ordinances by skilled operators, and precautions shall be taken to avoid damage. Rock shall be removed by line drilling where called for on plans and where directed by the engineer.

V. Classification of Excavated Materials.

All excavated materials shall be classified as earth or rock.

Earth = all excavation except rock, as follows:

Rock = ledge rock, concrete or masonry structures which require drilling or blasting, and boulders larger than $\frac{1}{3}$ cu. yd. in volume.

VI. Grading.

Specify as required. (See specification, "Grading for Roads, Airports, and Railroads.")

VII. Base for Slabs on Fill.

Fill to support paving may *or* may not be made from excavated material. (*Specify gravel, crushed stone, sand, or cinders, if excavated material is not to be used. Soil containing organic matter is unsuitable.*) Fill shall be compacted in 8-in. layers with a 5-ton roller. Hand *or* mechanical tampers shall be used for places inaccessible to roller. All walls liable to be disturbed by tamping or rolling shall be shored.

VIII. Backfilling.

All timber shall be removed and all trash shall be cleaned out from the excavation. Backfill shall be excavated material or ——. (*Specify material to be used.*) Backfill shall be placed in 8-in. layers and compacted by hand tamping. Backfill containing less than 10% clay may be puddled instead of tamped. Surface of backfill shall be left 6 in. above final grade to allow for settlement. After 3 months the contractor shall return and fill low spots.

IX. Clean-up.

All trash shall be removed. All excavated area shall be raked clean.

X. Payment.

Specify payment by lump sum agreed upon in contract. Provide clauses for payment of rock excavation per cubic yard as an extra. Measure rock excavation at 1 ft. 6 in. outside neat lines of foundations. Provide clauses for payment by time and material or unit price per cubic yard for excavation carried below elevations shown on plan if such excavation is authorized by the engineer. Provide clause for payment at unit price per linear foot for auger or pipe holes required by the engineer to further explore subsurface conditions below elevation of foundations shown on plans. Provide clause for payment at unit price or time and material for pumping and dewatering not specified. Provide clause for payment at unit price for underpinning not shown on plans or specified.

PILING

I. Scope.

Work Included. This contract shall include the furnishing and driving of all piles shown on drawings.

Work Not Included. Pile caps.

II. Type of Piles.

Omit type not included. For selection of type see "Data Book—Design."

Cast-in-Place Concrete Piles. Type A. These piles shall be formed by driving a shell to the required bearing, leaving the shell permanently in place, and filling it with concrete. Shells shall have sufficient strength and rigidity to permit their being driven and not to be distorted by soil pressure or the driving of adjacent piles; they shall be sufficiently watertight to exclude water during placing of concrete. Piles may be tapered or cylindrical. If tapered they shall increase uniformly in diameter or the diameter shall increase in uniform steps. The minimum diameter of tapered piles shall be 8 in. at the point and 14 in. at the head. The average diameter shall not be less than 11 in. The minimum diameter of cylindrical piles shall be $12\frac{3}{8}$ in.

Cast-in-Place Concrete Piles. Type B. These piles shall be placed by driving a heavy steel pipe casing with an interior core or point to required depth, removing the core and inserting a permanent steel shell, filling it with concrete, and then withdrawing the driving casing. Shells shall have sufficient strength and rigidity not to be distorted by soil pressure or the driving of adjacent piles, and they shall be sufficiently watertight to exclude water during placing of concrete. Shells shall be cylindrical with a minimum diameter of $12\frac{3}{8}$ in.

Cast-in-Place Concrete Piles. Type C. These piles shall be placed by driving a heavy steel pipe casing with an interior core or point to required depth, removing the core, and filling the driving casing with concrete while withdrawing same. The inside of the driving pipe shall be at least 14 in. in diameter, and no driving pipe shall be withdrawn until all piles within 10 ft., center to center, have been driven.

Steel Pipe Piles Filled with Concrete. Steel pipe piles shall conform to the A.S.T.M. Specs. A252-42T. Piles shall have a minimum inside diameter of 10 in. and a minimum shell thickness of $\frac{3}{8}$ in. except that the 10-in. and 12-in. piles may have a shell of $\frac{5}{16}$ in. They shall be driven without point but with open end *or* with cast-steel point. Piles up to 20 ft. in length shall be in one piece. (*Piles from 20 ft. to 40 ft. shall have not more than one splice. For longer piles, splices shall not be closer together than 20 ft.*)

Note. Specify open ends for piles to rock or hardpan, and point for friction piles, except that piles may have to be driven with open ends for predetermined distance in order not to disturb adjoining foundations, cleaned out, filled with concrete, and then driven to required resistance.

Precast Concrete Piles shall be of size and detail shown on plans. *Specify strength of concrete 4,000 lb., control, ingredients. See applicable portion of "Structural Concrete" specifications.*

No high-early-strength cement shall be used. Forms must be tight and rigid. Piles shall be marked with casting date and shall be cured for 30 days without handling or moving and at minimum temperature of 50° F.

The contractor shall drive enough test piles to determine the length of pile required to secure the specified bearing and to determine required penetrations in the various areas of the work. These tests shall be made sufficiently in advance of the pile driving to prevent delay in the progress of work and so that the contractor will have on hand, at all times, piles of proper length to meet any conditions that may arise.

Composite Piles shall consist of a concrete section from the cut-off to 1 ft. 0 in. below water level superimposed upon a wood pile. Details of splice and dimensions of pile shall be in accordance with drawings.

Wood Piles shall be ____ *(See "Suggested Grades and Species for Timber Specifications," p. 69).* They shall be sound, free from sharp crooks or bends or decay, and sufficiently straight so that a line drawn from the center of the head to the point will be wholly within the pile. The diameter at the point shall not be less than 7 in. for piles up to 40 ft. in length and not less than 6 in. for piles longer than 40 ft. At a point 2 ft. 0 in. from butt, piles less than 25 ft. 0 in. long shall have a minimum diameter of 10 in.; piles over 25 ft. 0 in. long shall have a minimum diameter of 12 in. All measurements shall be made under bark. *For more detailed specifications, see "Résumé of A.S.T.M. Spec. D-25," p. 77.*

Treated Piles. *If to be treated, specify as per "Wood Preservation and Painting," p. 67.*

Steel H Piles. Material shall conform to A.S.T.M. Spec. A7-36. Piles shall be structural steel sections as shown on plans.

III. Lines and Levels.

The contractor shall establish and locate all lines and levels and be responsible for the correct location of all piles.

IV. Concrete.

Specify strength of concrete for cast-in-place piles 2,500 lb., control, ingredients. See applicable portion of "Structural Concrete" specifications. Concrete shall be placed by bottom-dump bucket device in piles well cleaned of material and water by blowing.

V. Records.

The contractor shall keep a record of each pile driven and shall furnish signed typewritten copies daily.

The records shall give the diameter, length, location, type, safe load, penetration under the last five blows of the hammer, and the result of any tests.

VI. Drawings.

The contractor shall submit for approval, before the award of the contract, complete detail drawings and specifications of the different type of piles estimated upon and a written statement describing equipment to be used.

VII. Driving.

Piles shall be driven with a drop hammer or with a single-acting steam hammer of Vulcan type, the weight of whose striking part times its fall is at least 15,000 ft.-lb., to a safe bearing value of ____ tons, or to refusal for piles driven to rock or hardpan. The double-acting steam hammer of the Standard McKiernan-Terry type may be used when driving piles to refusal but shall not be used for other piles except with special permission of the engineer.

The ratio of the weight of pile F and the weight of the striking part of the hammer W shall be between the following limits: $\frac{F}{W} = \frac{1}{10}$ minimum to $\frac{F}{W} = 10$ maximum.

The safe value of piles shall be determined by the following formula:

$$P = \frac{2WH}{S+1} \text{ for drop hammer}$$

$$P = \frac{2WH}{S+0.1} \text{ for single-acting steam hammer}$$

$$P = \frac{2(W+Ap)H}{S+0.1} \text{ for double-acting steam hammer}$$

where P = safe load in pounds, W = weight of the striking part of the hammer in pounds, H = the fall in feet of the striking part of the hammer or stroke, S = average penetration per blow in inches under the last five blows, A = area of piston in square inches, and p = mean effective steam pressure.

Note. Where piles are driven to refusal on rock or hardpan, the allowable load should be based on values given in table shown on p. 2-62 in "Data Book—Design," or as determined from required code.

Driving shall be done with fixed leads which will hold the pile firmly in position and alignment and in axial alignment with the hammer. Suitable anvils or cushions, depending on the type of pile, shall be used to prevent undue damage of the pile butts.

Driving of all piles shall be continuous without intermission until the pile has been driven to final resistance. The tops of piles shall be cut off true and level at the elevations indicated on the drawings. All portions battered, split, warped or buckled, or damaged or imperfect in any way shall be removed.

Shells and casings shall have sufficient excess length to allow the complete removal of working tops. No tube or part of a tube that has been previously subjected to driving shall be used as a part of a pile. *Omit for wood piles.*

After each group of casings is driven to the required resistance, all water and other material shall be removed and the shell shall be inspected with a light. The casings shall be free from water when the concrete is being placed. No piles in a cluster shall be filled until all the piles in the cluster are driven. *Omit for wood piles and steel H piles.* Piles shall not be jetted except with the approval of the engineer. After jetting, piles shall be driven to the required resistance.

An upheaval of piling shall be corrected without extra cost to the owner and to the satisfaction of the engineer. The average pile length in a group shall be at least 10 ft.

VIII. Damaged and Misdriven Piles.

Broken or shattered piles will not be accepted.

Tolerances. Piles shall not be more than 2% out of plumb and not more than 3 in. out of place.

Should any pile be damaged by overdriving or not conform to the tolerances of the specification, an extra pile or piles shall be driven in its place.

Piles rejected after driving may remain in the ground at the discretion of the engineer, be filled with concrete, and be cut off as directed. When rejected piling is withdrawn, the space, if another pile is not driven into it, shall be filled solid with gravel or broken stone without payment therefor.

IX. Obstructions.

Where boulders or other obstructions make it impossible to drive certain piles in the location shown and to the proper bearing strata, the contractor shall resort to all usual methods to install piles as required, including spudding, jetting, or other feasible means. If, in the judgment of the engineer, the contractor is unable to complete properly any pile by resorting to such methods, the engineer may order an additional pile or piles driven for which the contractor will be paid in accordance with unit prices in the contract. Piles abandoned because of obstructions encountered before reaching the accepted bearing strata shall be filled with concrete and be paid for as completed piles.

Where directed by the engineer, excavation operations shall be conducted to remove obstructions at the owner's expense as covered in Section X, "Basis of Payment."

X. Basis of Payment.

Specify that the contractor is to be paid for work within limits shown on plan by lump sum or unit costs given in contract.

The contractor shall include in his bid unit prices for the following:

Both increase and decrease of the number of piles shown on the drawings, quoting a price per pile.

Both increase and decrease of total length of piling shown on drawings, quoting a price per linear foot.

Use of pile driver for extra work such as spudding, jetting, etc., quoting a price per hour.

Where obstructions require excavation or use of different type of piles, the contractor shall do the work on a time and material basis agreed upon in the contract.

XI. Tests.

Laboratory Tests. Tests of cement, concrete, and aggregates shall conform to applicable portions of specifications for "Structural Concrete."

		Number of Tests
Steel pipe piles	A.S.T.M. 252-42T	One tension test on one length of each lot of 200 or less.

Field Tests. One load test will be included in this contract. It shall be conducted as follows: *See "Data Book—Field."*

FOUNDATIONS

I. Scope.

II. Borings and Test Holes.

Subsurface information given on plan is for general information only. Its correctness or incorrectness shall not affect the provisions of the contract.

III. Inspection of Soil.

The general contractor shall notify the engineer when the excavating is completed, and no concrete shall be poured until the engineer has approved the soil for each individual footing.

The engineer may require the general contractor to bore not more than 8 ft. 0 in. under each footing with a pipe or auger without additional expense to the owner.

IV. Load Tests.

The general contractor shall perform a load test on the soil at cost plus 10% for overhead and profit if required by the engineer.

V. Ground-Water Level.

If ground-water level is found to be above the lowest pits, or if springs are encountered, the general contractor shall advise the engineer and shall not proceed with the foundation work until the engineer has issued instructions as to a method of taking care of this condition.

VI. Pumping and Cofferdams.

The contractor shall keep the site clear of water at all times. To this end he shall provide cofferdams and pumping as required without cost to the owner.

VII. Underpinning.

The contractor shall submit the plan of underpinning and shoring for the approval of the engineer.

VIII. Difference in Level of Foundations.

Any difference in level of foundations which violates safe slopes of material shall, where shown on plans, be taken care of by steel sheet piling or carefully placed breast boards, all work to be performed by specialists and with plans approved by the engineer.

Include in this general specification any other items such as: exploratory drilling of rock; channeling rock and omitting blasting; submission of underpinning plans for approval.

Include specifications for piling, general excavation, waterproofing, concrete, masonry, etc., as required.

IX. Basis of Payment.

MASONRY (BRICK, CLAY-TILE, AND CONCRETE BLOCK)

I. Scope.

Work Included. This contract shall include the furnishing and installing complete of all brickwork, structural clay-tile, and concrete blocks shown on plans and as specified.

Work Not Included.

II. Material.

Water shall be clean and free from oil, acids, salt, or injurious substances.

Portland Cement shall conform to the Standard Specifications of A.S.T.M. C-150, latest edition. It shall be a standard product, the name of which shall be submitted to the engineer for approval.

Lime shall conform to the Standard Specifications of A.S.T.M. C-6, latest edition, for quicklime, or A.S.T.M. C-5, latest edition, for hydrated lime.

Lime Putty may be prepared from hydrated lime or quicklime. Hydrated lime shall be mixed with water to form a putty and stored with reasonable care to prevent evaporation for at least 24 hr. before use. Quicklime shall be slaked with enough water to make a cream, passed through a No. 10 sieve, and then stored with reasonable care to prevent evaporation for at least 7 days before use.

Sand shall conform to the specifications of the A.S.T.M. C-144, latest edition. For joints of average thickness, 100% of the sand shall pass through a No. 8 sieve and not more than 15% to 35% through a No. 50 mesh sieve.

Brick, Common and Face. Clay and shale common brick shall conform to the Standard Specification of the A.S.T.M. C-62, latest edition. They shall be Grade ____ for facing and Grade ____ elsewhere.

Sand Lime Brick shall conform to the Standard Specification of the A.S.T.M. C-73, latest edition. They shall be Grade ____ for facing and Grade ____ elsewhere.

Specify either Grade MW or Grade SW for facing except where brick may be subjected to temperatures below freezing while permeated with water, and then use Grade SW. (MW = medium weather; SW = severe weather; NW = no weather.)

Specify Grade NW for brick other than facing when they are not subjected to action of weather or soil, and Grade MW brick when they are subjected to weather or soil.

Specify lower limit of absorption according to local practice, or *6%.*

Face Brick shall be common brick *or* the type selected by the engineer. The contractor shall allow $____ per M for the cost of the face brick delivered to the site.

Structural Hollow Clay-Tile shall conform to the Standard Specification of the A.S.T.M. C-34, latest edition, for load-bearing tile, and A.S.T.M. C-56 for non-load-bearing tile. Load-bearing tile shall be Grade ____. *Specify Grade LBX when they will be subjected to the action of weather or soil; otherwise use Grade LB.* Non-load-bearing tile shall be Grade NB; *non-load-bearing tile may be specified for skeleton wall back-up.*

Concrete Blocks shall conform to the Standard Specification of the A.S.T.M. C-90, latest edition, for load-bearing block. Blocks shall be cured damp for at least 7 days.

Specify either cinder or stone aggregate.

Back-Up Blocks may be either clay-tile or concrete.

Mortar (**Cement**) shall be 1 part Portland cement and 3 parts sand tempered with lime putty not over 25% of cement volume.

Mortar (**Lime-Cement**) shall be 1 part cement, 1 part lime putty, and 6 parts sand by volume. It shall be mixed dry and then wetted to proper consistency for use. No mortars that have stood for more than 1 hr. shall be used. A mortar which shows a tendency to become dry before this time shall have water added to it and shall be remixed.

Masonry Cement shall conform to Standard Specifications of the A.S.T.M. C-91, latest edition, and when used must be approved by the engineer.

III. Workmanship.

Laying of Brick. All brick shall be laid up with (lime-cement) mortar. All brick, except face brick, shall be thoroughly wet before laying, but brick laid in freezing weather must be protected from the formation of ice. Common brick shall be laid with a shove joint in full mortar beds, and be thoroughly slushed up with mortar at every course. Face brick shall be laid on full mortar beds and have all vertical joints completely filled with mortar. Exterior face brick shall be laid in advance of backing and shall have the back parged with a full $\frac{1}{2}$ in. of setting mortar so as to form a continuous coat except where broken by bonding headers or ties.

All brickwork shall be plumb, square, and true to dimensions shown and in bond hereinafter specified.

All brickwork shall be built tightly against columns, floor slabs, or other structural parts. Around window and door frames, brickwork shall be kept back a sufficient distance to permit a calked joint.

Where drawings indicate that structural steel columns are to be fireproofed with brickwork, the brick shall be built closely against all flanges and webs with all spaces between the steel and the brickwork filled solid with setting mortar.

Steel members embedded in masonry and not indicated to be fireproofed with concrete shall be "buttered" with not less than $\frac{1}{2}$ in. of setting mortar.

Height of Courses. Common brick shall be laid in joints not more than $\frac{1}{2}$ in. thick. Exterior and interior face brick shall be laid with joints of ____ thickness.

Bond. Common brick shall be laid five stretcher courses to one header course. Face brick shall be laid in ____ bond. *For typical bonds see p. 1-12 in "Data Book—Design."*

Pointing. Joints of all interior face brickwork shall be neatly struck. Joints of all face brick and all common brick exposed to the exterior shall be finished with a slightly concave pointing tool applied so as to compact setting mortar and form a close and continuous contact with the brick.

Laying of Structural Clay-Tile or Concrete Blocks. Structural clay-tile or concrete blocks shall be set in (lime-cement) mortar where they are used for exterior or party wall or for pier construction. The work shall be built plumb and true to the given dimensions, with tile or blocks always set to bond and breaking joints. Where the blocks or tile are set with the cells horizontal, they shall be set in a full bed of mortar, not exceeding $\frac{1}{2}$ in. in thickness, with the vertical joints buttered full on walls and webs; where they are set with the cells vertical, the bearing members shall be buttered and the vertical joints slushed full of mortar.

Laying of Back-Up Walls. Concrete block or clay-tile shall be so arranged that brick headers as required by bond shall extend into the main wall.

Laying of Veneered Wall. Veneer shall be tied into the masonry backing, either by a header for every 300 sq. in. of wall surface or by substantial non-corroding metal ties spaced not farther apart than 16 in. vertically and 24 in. horizontally. Headers shall project at least $3\frac{3}{4}$ in. into the backing. Special care shall be taken to fill all joints flush with mortar around the openings.

Laying of Cavity Walls. In cavity walls the back and facing shall be securely tied together with a $\frac{3}{16}$-in.-diameter steel rod or metal tie of equivalent stiffness, coated with a non-corroding metal or some other approved protective coating, for every 3 sq. ft. of wall surface.

Cold-Weather Protection. Masonry shall be protected in the same manner as structural concrete. *(See applicable portion of "Structural Concrete" specifications.)*

Cleaning. All walls of common brick, clay-tile, or concrete block that are exposed on the exterior or forming finished interior surfaces shall be cleaned at the completion of the building.

All face brick, at final completion or when it is so directed by the engineer, shall be washed down, cleaned, and pointed.

In extreme cases a 5% solution of muriatic acid may be used for the cleaning of exterior brickwork, but it shall be preceded and followed by a copious bath of fresh clean water.

IV. Tests.

Laboratory Tests. The method of testing shall be according to the latest revision of the following:

		Number of Tests
Portland cement		*See "Structural Concrete" specifications.*
Sand		*See "Structural Concrete" specifications.*
Masonry cement	A.S.T.M. C-91	Test of 5-lb. sample per 300 bbl.
Quicklime	A.S.T.M. C-110	Test of $2\frac{1}{2}$-kg. (5-lb.) sample.
Hydrated lime	A.S.T.M. C-110	Test of $2\frac{1}{2}$-kg. (5-lb.) sample.
Brick clay shale *	A.S.T.M. C-67	5 tests for each lot of 50,000 units or less.
Brick sand lime *	A.S.T.M. C-67	5 tests for each lot of 50,000 units or less.
Structural clay-tile *	A.S.T.M. C-112	5 tests for each lot of 100 tons or less.
Concrete block *	A.S.T.M. C-140	5 tests for each lot of 50,000 units or less.

Field Test. Sieve analysis of sand shall be made from time to time as appearance indicates.

* From field sample. Also, manufacturer should submit samples or report before start of job.

STONE MASONRY

I. Scope of Work.

Work Included.

Work Not Included.

II. Material.

Material shall be sound and free from seams or cracks. Each bidder shall submit a sample of the stone he proposes to use together with the name of the quarry. These samples shall be approved by the engineer before bids are submitted.

III. Ashlar Masonry.

Ashlar shall be (*specify*) granite, limestone, etc., and shall consist of first-class cut stone masonry laid in regular courses, and shall include all work in which, as distinguished from rubble masonry, the individual stones are dressed or tooled to exact dimensions.

The work shall be carried out as per the latest A.A.S.H.O. Standard Specifications for Highway Bridges. The following are excerpts from the 1944 edition which will govern in case of differences.

1. Stone shall be kept free from oil, dirt, or any other injurious material which may prevent the proper adhesion of the mortar or detract from the appearance of the exposed surfaces.

2. Mortar for laying the stone and pointing shall be composed of 1 part Portland cement and 3 parts sand unless otherwise provided. Sand shall conform to the specifications of the A.A.S.H.O. M 45, latest edition. For joints of average thickness, 100% of the sand shall pass through a No. 8 sieve and not more than 15% to 40% through a No. 50 mesh sieve.

3. Size of Stone. The individual stones shall be large and well proportioned. They shall not be less than 12 or more than 30 in. in thickness. The thicknesses of the courses, if varied, shall diminish regularly from the bottom to the top of the wall. The size of ring stones in arches shall be as shown on the plans.

4. Surface Finishes of Stone. For the purpose of this specification the surface finishes of stone are defined as follows:

Smooth-finished: Having a surface in which the variations from the pitch line do not exceed $\frac{1}{16}$ in.

Fine-finished: Having a surface in which the variations from the pitch line do not exceed $\frac{1}{4}$ in.

Rough-finished: Having a surface in which the variations from the pitch line do not exceed $\frac{1}{2}$ in.

Scabbled: Having a surface in which the variations from the pitch line do not exceed $\frac{3}{4}$ in.

Rock-faced: Having an irregular projecting face without indications of tool marks. The projections beyond the pitch line shall not exceed 3 in., and no part of the face shall recede back of the pitch line.

5. Dressing Stone. Stones shall be dressed to exact sizes and shapes before being laid and shall be cut to lay on their natural beds with top and bottom truly parallel.

Beds of face stone shall be fine-finished for a depth of not less than 12 in. Vertical joints of face stone shall be fine-finished and full to the square for a depth of not less than 9 in.

6. Stretchers shall have a width of bed of not less than $1\frac{1}{2}$ times their thickness. They shall have a length of not less than twice their thickness, or less than 3 ft., and not more than $3\frac{1}{2}$ times their thickness.

7. Headers shall be placed in each course and shall have a width of not less than $1\frac{1}{2}$ times their thickness. In walls having a thickness of 4 ft. or less, the headers shall extend entirely through the wall. In walls of greater thickness, the length of the headers shall be not less than $2\frac{1}{2}$ times their thickness, when the course is 18 in. or less in height, and not less than 4 ft. in courses of greater height. Headers shall bond with the core or backing not less than 12 in. Headers shall hold in the heart of the wall the same size as that shown in the face and shall be spaced not farther apart than 8 ft. center to center. There shall be at least one header to every two stretchers.

8. Cores and Backing shall consist either of roughly bedded and jointed headers, as specified above, or of Class ____ or ____ concrete, as may be specified.

9. Laying Stone. Stone masonry shall not be constructed in freezing weather or when the stone contains frost, except with written permission of the engineer, and subject to such conditions as he may require.

10. Face Stone. Joints and beds shall be not less than $\frac{3}{8}$ in. or more than $\frac{1}{2}$ in. in thickness, and the thickness of the joint or bed shall be uniform throughout.

The stones in any one course shall be placed so as to form bonds of not less than 12 in. with the stones of adjoining courses. Headers shall be placed over stretchers, and, in general, the headers of each course shall equally divide the spaces between headers of adjoining courses, but no header shall be placed over a joint and no joint shall be made over a header.

11. Dowels and Cramps. Where required, coping stone, stone in the wings of abutments, and stone in piers shall be secured with wrought-iron cramps or dowels as indicated on the plans.

Dowel holes shall be drilled through each stone before the stone is placed, and, after it is in place, such dowel holes shall be extended by drilling into the underlying course not less than 6 in.

Cramps shall be of the shapes and dimensions shown on the plans or approved by the engineer. They shall be inset in the stone so as to be flush with the surfaces.

Cramps and dowels shall be set in lead, care being taken to fill the surrounding spaces completely with the molten metal.

12. Copings. On piers, not more than two stones shall be used to make up the entire width of coping, and the copings of abutment bridge seats shall be of sufficient width to extend at least 4 in. under the backwall. Each step forming the coping of a wing wall shall be formed by a single stone which shall overlap by at least 12 in. the stone forming the step immediately below it.

Tops of copings shall be given a bevel cut at least 2 in. wide, and beds, bevel cuts, and tops shall be fine-finished. The vertical joints shall be smooth-finished, and the copings shall be laid with joints not more than $\frac{1}{4}$ in. in thickness. The under sides of projecting copings, preferably, shall have a drip bead.

Joints in copings shall be located so as to provide not less than a 12-in. bond with the stones of the under course, and so that no joint will come directly under the superstructure masonry plates.

13. Pointing shall not be done in freezing weather or when the stone contains frost. It shall be done before the mortar is set or else the joints shall have been raked out to a depth of 2 in. before the mortar has set. Pointing shall be done with an approved pointing tool.

IV. Mortar Rubble Masonry.

Mortar rubble masonry shall be coursed, random, *or* random range work (*specify*) (*see p. 1-13 of "Data Book—Design"*) and shall consist of roughly squared and dressed stone laid in cement mortar.

The work shall be carried out as per the latest A.A.S.H.O. Standard Specifications for Highway Bridges. The following are excerpts from the 1944 edition which will govern in case of differences.

1. Mortar shall be 1 part cement and 3 parts sand, unless otherwise provided.

2. Size. Individual stones shall have a thickness of not less than 8 in. and a width of not less than $1\frac{1}{2}$ times their thickness. No stones, except headers, shall have a length less than $1\frac{1}{2}$ times their width. Stones shall decrease in thickness from the bottom to the top of the wall. The size of ring stones for arches shall be as shown on the plans.

3. Headers shall hold in the heart of the wall the same size as that shown in the face, and shall extend not less than 12 in. into the core or backing. They shall occupy not less than $\frac{1}{5}$ of the face area of the wall and shall be evenly distributed. Headers in walls 2 ft. or less in thickness shall extend entirely through the wall.

4. Shaping Stone. The stones shall be roughly squared on joints, beds, and faces. Selected stone, roughly squared and pitched to line, shall be used at all angles and ends of walls.

5. Laying Stone. Stone masonry shall not be constructed in freezing weather or when the stone contains frost, except by written permission of the engineer and subject to such conditions as he may require.

All stone shall be laid in its natural bed. Joints and beds shall have an average thickness of not more than 1 in.

Whenever possible the face joints shall be properly pointed before the mortar becomes set. Joints which cannot be so pointed shall be prepared for pointing by being raked out to a depth of 2 in. before the mortar is set. The face surfaces of the stones shall not be smeared by the mortar forced out of the joints or that used in pointing.

The vertical joints in each course shall break joints with those in adjoining courses at least 6 in.

STRUCTURAL CONCRETE (BRIEF SPECIFICATION)

I. Scope of Work.

II. Working Drawings.

The contractor shall submit working drawings, showing dimensions, bar schedules, bending details, and stirrup spacings, for the approval of the engineer.

Lithoprints of the engineer's drawings shall *or* may be obtained at the contractor's expense to form the basis of these working drawings.

Details shall be carried out in accordance with A.C.I. rules.

III. Concrete. (*Specify either "fixed ratios" or "controlled concrete."*)

Fixed Ratios. The concrete shall be proportioned as shown on the plan, by volume. The total water content shall be not more than ____ gal. per sack of cement, and the slump shall not be greater than 4 in. for any mix. This concrete shall develop a strength of ____ lb. per sq. in. at 28 days.

For each 150 cu. yd. of concrete, 4 cylinders shall be taken in accordance with A.S.T.M. Specification D-31, 2 of which shall be broken at 7 days and 2 at 28 days.

Controlled Concrete. The contractor shall furnish concrete which shall develop a strength of ____.

The strength is to be determined by 4 cylinders for each 150 cu. yd. of concrete (but not less than 4 cylinders for each day's pour) of which 1 shall be broken at 7 days and 3 at 28 days.

The contractor shall submit the mix that he intends to use, which must be proved by preliminary cylinder tests at least 30 days before the operation.

These proving tests shall consist of at least 4 cylinders for each specified mix, and these cylinders must show a strength at 28 days 15% higher than the ultimate strength called for.

The cylinders shall be made and stored in accordance with A.S.T.M. Specification D-31, latest edition.

The water content shall not be increased from the amount shown in the design mix unless an equal proportion of cement is added. The slump shall not be greater than 4 in. for any mix.

The engineer may call for additional cement without extra cost to the owner if the mix adopted does not attain the required strength.

IV. Cement.

All cement shall be Portland and shall conform to the A.S.T.M. requirements C-150-Type I, and shall be tested by a laboratory selected by the engineer.

V. Sand.

Sand shall be capable of developing 90% of the tensile strength of standard Ottawa sand. Samples shall be submitted for the engineer's approval and for testing.

Sand shall not contain more than 3% clay. Sand shall not show darker than a very light amber when tested by the colorimetric method.

The size of the sand shall be such that not less than 85% shall pass through a $\frac{1}{4}$-in. sieve, not more than 30% through a 50-mesh sieve, and not more than 5% through a 100-mesh sieve.

VI. Stone or Gravel.

Aggregate shall be composed of hard crystalline rock or gravel, free from shale or decomposed pieces. It shall be uncoated and clean. Samples shall be submitted to the engineer for approval.

For reinforced work it shall be graded between a $\frac{1}{4}$-in. ring and a 1-in. ring. For mass masonry it may be graded up to a 3-in. ring. Bank or crusher run will not be permitted.

The water shall be clean.

VII. Reinforcing Steel.

Reinforcing steel shall be new billet stock of intermediate grade, in accordance with the latest A.S.T.M. specification. The contractor shall furnish the engineer with a certificate from the manufacturer stating that the product is open-hearth steel and giving those chemical and physical properties of the heat required by the latest A.S.T.M. specification.

Bars shall be free from scale, oil, and structural defects and shall be kept so on the job.

The system of holding bars in place must insure that all steel in the top surface will support the weight of the workmen without displacement.

All reinforcing steel within the limits of a day's pour shall be in place and firmly wired before concreting starts.

Placing or wiring steel less than 6 hr. before concreting starts shall not be permitted.

On exterior exposed work, no ties or spacers shall be permitted to remain within $\frac{3}{4}$ in. of the finished surfaces.

VIII. Mixing.

The mix shall be kept as dry as possible to work.

Sand and stone shall be measured in gated hoppers.

A standard type of batch mixer shall be used.

Air-slaked cement or cement which is lumpy, whatever the cause, shall not be used.

The mixing time shall be not less than $1\frac{1}{2}$ min.

IX. Placing of Concrete.

Forms shall be clean.

Approved mechanical vibrators shall be used.

Contact with forms shall be insured by spading.

Bars shall be shaken to insure contact with concrete.

Slabs and beam stems shall be poured in one operation.

Plumb bulkheads shall be used at joints for day's work. They shall be arranged at right angles to the plane of stress and in areas of minimum shear.

The finished concrete shall be kept damp for 1 week after pouring, *or* floors and vertical surfaces may be sprayed with an approved preparation to retard the evaporation of water if spraying is not objectionable on account of subsequent finish.

Concrete columns and walls shall be allowed to set at least 3 hr. before the floor is poured.

X. Forms and Centering.

The contractor shall furnish forms that result in correctly aligned concrete. The following are suggestions to that end.

The centering shall be true and rigid, thoroughly braced both horizontally and diagonally, sufficiently strong to carry the dead weight of the construction, as liquid, without deflection, and tight enough to prevent material leakage of mortar.

For exposed exterior and interior concrete surfaces, plywood forms, thoroughly cleated and tied together for columns and walls with approved devices, shall be used.

Rigid care shall be exercised in seeing that all columns are plumb and true, and thoroughly cross braced to keep them so.

All floor and beam centering shall be crowned not less than $\frac{1}{4}$ in. in all directions for every 16 ft. of span.

Beveled strips shall be provided in corners of columns and beam boxes for chamfering of corners.

Forms. Temporary openings shall be provided at the base of column and wall forms, and at other points where they are necessary, to facilitate cleaning and inspection immediately before concrete is deposited. These forms shall not be removed until the concrete is adequately set.

When the forms are removed, the contractor shall place adequate reshores to prevent injury to the concrete by construction loads. The responsibility for safe practice in this regard shall be the contractor's.

See also Section XII, "Exposed Surfaces."

XI. Slots, Recesses, Sleeves, etc.

The contractor shall cooperate with all other trades in permitting the forming and setting of slots, recesses, chases, sleeves, inserts, bolts, hangers, etc., and of other trades not in his contract.

XII. Exposed Surfaces.

Interior. Imperfect surfaces where strength is not impaired may be patched and rubbed smooth with Carborundum brick.

Fins shall be removed, and the concrete surface affected thereby shall be rubbed smooth.

Exterior. Imperfect exterior surfaces shall not be patched but shall be repaired by removal and replacement of the member.

Forms shall be fitted tightly so as to minimize fins *or* form joints shall be finished with beveled stubs as directed by the engineer.

The exterior shall be kept damp for 2 weeks.

Construction joints in exterior work shall not be permitted, except where they are shown on the plan, and then they shall be in accordance with detail.

XIII. Floor Finishes.

Floor finishes shall be monolithic *or* bonded.

Monolithic Finish. Base concrete shall be very dry, containing 4 to 5 gal. of water per sack. The finish shall be 1 part cement and $2\frac{1}{2}$ parts sand. The sand shall be dried before being used and the finish shall be mixed in a dry mixer.

Application. The finish shall be applied as a dry top dressing, $\frac{1}{8}$ in. to $\frac{1}{4}$ in. thick. It shall be thoroughly floated and troweled only long enough to make it smooth.

Bonded Finish. The slab shall be brought to a true surface, $\frac{3}{4}$ in. below the finished floor elevation, and it shall be roughened by being raked as it sets. At a later date when it is time to apply the finish, the slab shall be

thoroughly cleaned by brushes and with a small jet from a high-pressure hose. All dirt shall be removed from crevices and depressions.

When the finish is ready to place, the floor shall be wet with 1 : 1 grout, and $\frac{3}{4}$ in. of granolithic finish shall be applied, as dry as it is possible to work. It shall be screeded, floated, and troweled to a smooth, hard finish.

Granolithic Finish shall consist of 1 part cement, 1 part sand, and $1\frac{3}{4}$ parts of clean, sharp $\frac{1}{4}$-in. grit, mixed with about 3 gal. of water per bag of cement for machine mixing and a slump of 4 in. for hand mixing, the exact amount depending on the amount of water in the sand, grit, and slab below.

Machine Finish. (*Alternative to ramming and floating bonded finish by hand.*) The finish shall be screeded after ramming and the surface shall be rolled with rollers weighing not less than 20 lb. per in. of length for a diameter of 14 in. or less.

The rolled surface shall then be floated with machine floats; the machine operator shall add water in very small quantities a few inches ahead of the floater.

The floor shall be troweled twice by hand, unless it is a stuck down floor, which shall be troweled only once.

XIV. Protection.

All floor finishes shall be protected by flooding within 24 hr. and covering immediately with non-absorptive roofing paper, lapped 2 in. and weighing not less than 35 lb. per 100 sq. ft. This paper shall remain in place at least 2 weeks and shall be protected from traffic by runways supported on smooth blocks.

This method of protection may be waived with the consent of the engineer in favor of an approved spray to retard evaporation and prevent unduly rapid drying out.

XV. Roof Grading.

The roof shall be filled to $\frac{1}{2}$ in. below finished elevation with 1 : 10 cinder concrete and shall be finished with $\frac{1}{2}$ in. of 1 : 3 cement mortar. Cinders shall be anthracite, clean, and well burned.

XVI. Ribbed Joist Construction.

Ribbed concrete joists shall be formed by the use of an approved system of removable metal cores.

The details of fastening furring shall be as shown on the plan.

XVII. Frost Protection.

The aggregate shall be free from frozen lumps or snow.

The concrete shall be kept at a temperature of 70° F. for 72 hr. after pouring.

The contractor shall submit for the engineer's approval the methods he intends to use to carry out the above requirements.

No admixtures to prevent freezing will be permitted.

XVIII. Load Tests.

In addition to the cylinder tests mentioned under "Controlled Concrete," if there exists evidence of faulty workmanship, violation of specifications, or likelihood of concrete having been frozen, load tests may be required, which shall be made at the contractor's expense under the direction of the engineer.

XIX. Extra Reinforcing Steel and Concrete.

The contractor shall include in his bid the furnishing and setting of ____ tons of reinforcing steel and ____ cu. yd. of concrete of the specified proportions, in addition to that shown and specified.

Credit shall be allowed the owner for the portion of the above amounts not used.

However, it is understood that the above changes do not materially change the character of the work.

XX. Transit Mix.

Transit-mixed concrete may be used, provided that it conforms to the specifications and tests herein described and further provided that the central plant producing the concrete, the equipment, and the transporting of it are, in the opinion of the engineer, suitable for the production and transportation of the specified concrete.

XXI. Laboratory Tests.

Cement: One test for each 400 bbl. Cars shall be sealed or bags tagged.

Sand: One sample at start of job, to be repeated if any change is noted in the bank.

Cylinders: Four per 150 yd. of concrete but not less than 4 for each day's pour. Preliminary test for controlled concrete: 4 cylinders minimum.

XXII. Field Tests.

Sand sediment test (milk bottle).

The cylinders for above laboratory tests shall be made, stored, and shipped.

Slump tests shall be conducted continuously during concreting operations.

STRUCTURAL CONCRETE (FULL SPECIFICATION)

I. Scope of Work.

II. Working Drawings.

Working drawings shall be submitted by the contractor showing dimensions, bar schedules, bending details, and stirrup spacing for the approval of the engineer. The making of these drawings shall not be sublet without the engineer's permission.

Lithoprints of the engineer's drawings shall *or* may be obtained at the contractor's expense, to form the basis of the working drawings.

Details shall be carried out in accordance with A.C.I. rules and in accordance with the following instructions to detailers. *Copy parts applicable from the following list.*

Indicate mix or strength of concrete on plans.

A.C.I. rules shall be followed as to stirrups, column ties, and anchorages. The design is based on ____ $f'c$. Details of web reinforcement and anchorages shall be carried out accordingly, unless they are otherwise shown. *See pp. 1-01 and 1-25 in "Data Book—Design."*

Where concrete beams frame into steel, two $\frac{3}{4}$-in. round anchor bolts shall be provided, with double nuts through web or hooks over flanges, except as otherwise noted.

____ header bars shall be provided in the slab in front of all openings and chases in bearing walls unless otherwise shown.

Metal tile slabs shall be anchored to walls with $\frac{5}{8}$-in. round anchors, 4 ft. 0 in. long, with 6-in. hook, at wall end, placed in alternate joists.

Metal tile joists shall be 25 in. o.c. except as shown. The steel shown in slab schedules is per joist.

The topping of metal tile joist slabs shall be 2 in. thicker than typical each side of concrete beams parallel to joists.

Where joists run parallel to wall $\frac{1}{2}$-in. round anchors shall be provided, 3 ft. 6 in. long with 6 in. hooks, at right angles to joists 4 ft. 0 in. o.c. in 2-in. topping.

Working drawings shall show tee flanges on beams of sufficient width and thickness to develop full strength of steel.

Quarter-inch round stirrups, 12 in. o.c., shall be provided for beams and joists with top steel where no stirrups are called for.

Tie rods $\frac{3}{8}$-in. round shall be provided in top of all concrete beams, to fasten stirrups where no top steel occurs.

Quarter-inch round rods 12 in. o.c. shall be provided at right angles to joists in top of all metal tile and joist slabs.

Longitudinal or temperature reinforcement shall be provided in solid slabs as per A.C.I. code. *See p. 1-29 in "Data Book—Design."*

One hundred per cent continuity shall be provided over supports for all continuous slabs, beams, and joists unless otherwise noted.

In all solid slabs alternate bars shall be bent up and extended into adjacent spans where slabs are continuous unless it is otherwise noted on the plans.

Rods $\frac{3}{8}$-in round, 12 in. o.c., shall be provided, extending into the slab 2 ft. 0 in. each side of beam where solid slabs are parallel to beams. Where slab occurs on one side only, a 6-in. hook shall be provided.

All negative moment rods shall extend to quarter points of spans.

At the ends of non-continuous beams anchor bars shall be provided in the top of the beam. Anchors shall be equivalent to $\frac{1}{3}$ of the main reinforcement, but not less than two $\frac{3}{4}$-in. round x 4 ft. 0 in. unless noted.

Steel bars in non-continuous beams shall be provided with hooks where they are required by A.C.I. code.

At the supports of continuous beams, bottom bars shall be extended beyond the center of support as shown on the detail and as required for anchorage in accordance with A.C.I. code. Where 3 bars occur, 2 bars shall be lapped from each side.

III. Cooperation.

The contractor shall cooperate with all other trades in permitting the forming and setting of slots, recesses, chases, sleeves, inserts, bolts, hangers, openings and equipment not in his contract.

IV. Materials.

Cement. Cement shall conform to the latest revision of A.S.T.M. Specification C-150, type ____. *Specify one or more of the following types:*

Guide to engineer in specifying cement:

Type I. Specify generally.

Type II. Specify for exposed and heavy structures and important highway and airport pavements. (Moderate heat and sulfate resistance.)

Type III. Specify only for emergency construction and repairs. (High early strength.)

Type IV. Specify only for mass concrete. (Low heat and slow curing.)

Type V. Specify for concrete exposed to alkali, such as sea water and alkali soils and water. (High sulfate resistance and strength.)

White cement shall conform to A.S.T.M. Specification C-150.

Aggregates shall conform to all provisions and test methods of A.S.T.M. C-33, with the following limitations. (Or *specify clean, hard particles of crushed stone or gravel.)*

Soundness (Sulfate) Test. Loss in 5 cycles shall be not more than 12% for fine aggregates or less than 15% for coarse aggregates.

Colorimetric Test (Fine Aggregate). The color shall be light amber.

Sieve Analysis.

COARSE AGGREGATE

PERCENTAGE PASSING SQUARE OPENINGS

Size sieve equal to maximum aggregate size	Size sieve equal to $\frac{1}{2}$ maximum aggregate size	No. 4 sieve
95–100	35–70	0–10

Maximum Aggregate Size. *Specify.*

Reinforced concrete, $\frac{3}{4}$ distance between bars, usually $\frac{3}{4}$-in. size.
Thin sections, $\frac{1}{5}$ narrowest dimension between forms.
Ordinary plain concrete, foundations, etc., $1\frac{1}{2}$ in. to 2 in.
Heavy mass concrete, 2 in. to 6 in.

FINE AGGREGATE

Percentage Passing Square Openings

No. 4	No. 16	No. 50	No. 100	No. 200
95–100	45–70	15–30	3–8	0–5

Fineness modulus shall not vary more than plus or minus 0.20 from that of the approved sample.

Water shall be clean and free from oil, acids, salt, or injurious substances.

Specify test by A.A.S.H.O. T-26 pH value 4.0 to 8.5 when water is alkaline, salt, or suspected of containing industrial wastes.

Reinforcing Steel shall be new billet stock of structural or intermediate grade conforming to the following:

A.S.T.M.	Type
A-15	Bars and rods
A-185	Steel wire fabric

V. Storage of Materials.

Cement shall be stored off the ground in a dry ventilated building.

Aggregates shall be stored in 2-ft. layers on planking. Each size shall be kept separate, with wooden bulkheads between adjacent piles.

Reinforcing Steel shall be stored under cover and protected from rusting, oil, grease, or distortion. Only steel needed for immediate use shall be removed from storage.

VI. Concrete.

Specify either by fixed ratio or controlled concrete as follows:

Fixed Ratios *are recommended only when accurate control is impracticable.*

Concrete shall be, by volume, of those proportions that are shown on the plans. The concrete shall be as dry as is practicable for working into the forms and around the reinforcement. This concrete shall develop a strength of ____ lb. per sq. in. at 28 days.

Controlled Concrete shall conform to the following requirements. *Tabulate herein the strengths of concrete required.*

Class of Concrete	28-Day Compressive Strength

Design Mix. The contractor shall submit mix designs for each strength, stating the proposed slump and the proportional weights of cement, saturated surface dry aggregates, and water. These mixes shall be proved by preliminary tests 30 days before concreting and shall show a 28-day strength 15% higher than the ultimate required.

Proportions. The proportions of the concrete shall be such as to work readily into the form angles and around the reinforcement without excessive manipulation, segregation, or water gain.

The percentage of sand to total aggregate shall lie between ____. *See p. 1-28 in "Data Book—Design."*

The water content and slump shall be ____. *See limits given in the table on p. 1-28 in "Data Book—Design."*

Job Mix Adjustment. The water content shall not be increased from the amount required by the design mix unless cement at required water-cement ratio is added. The engineer may require additional cement without extra compensation to the contractor if the mix adopted does not produce the required strength.

Load Tests may be required when the average strength of job control cylinders falls below the required strength. When the test is demanded, the member under consideration shall be subjected to a superimposed load of $1\frac{1}{2}$ times the live load plus $\frac{1}{2}$ the dead load, to be left in position for 24 hr. If the member shows evident failure, such changes as are necessary to make the structure adequate shall be made; or, where lawful, a lower rating shall be established.

The member shall pass the test if the maximum deflection at the end of 24 hr. does not exceed D, where $D = \dfrac{0.001L^2}{12t}$.
If the deflection exceeds D in the formula the member shall have passed the test if the member recovers at least 75% of observed deflection within 24 hr. after the load is removed.

VII. Batching of Concrete.

Aggregates and bulk cement shall be measured to within 1% by weight. Cement in standard sacks need not be weighed. Water shall be measured by volume or by weight to within $1\frac{1}{2}$%.

The complete plant assembly shall be approved by the engineer and shall conform to the following requirements: ready adjustment of aggregate weights for varying moisture contents; proportion of water to cement accurately controlled and easily checked; accurate control of all materials with positive shut-off; facilities for prompt removal of excess materials in hoppers; visible dial or balance indicators; each specified size of aggregate measured separately with a separate beam scale; bulk cement dropped through canvas drop chute or telescopic flexible hose tremie; ten 50-lb. test weights provided. When checked in increments of 500 lb. the weighing apparatus shall be accurate to within 0.004 to and including the heaviest batch weight expected.

VIII. Transporting Materials.

Carriers shall have batch partitions tight enough to prevent loss and high enough to prevent intermingling of materials when dumping. Bulk cement shall be transported in separate compartments of adequate size attached to and operated with each batch release gate.

Sacked cement shall be transported unopened and shall be completely emptied into mixer skip at the site. Waterproof covers shall be provided for all batch carriers.

IX. Forms.

The contractor shall provide forms that will produce correctly aligned concrete.

The centering shall be true and rigid, and thoroughly braced both horizontally and diagonally. The forms shall be sufficiently strong to carry the dead weight of the concrete as a liquid without deflection, and tight enough to prevent material leakage of mortar.

For exposed interior and exterior concrete surfaces of columns and walls, plywood or other approved forms, thoroughly cleated and tied together with approved devices, shall be used.

Rigid care shall be exercised in seeing that all columns are plumb and true, and thoroughly cross-braced to keep them so.

All floor and beam centering shall be crowned not less than $\frac{1}{4}$ in. in all directions for every 16-ft. span.

Beveled strips shall be provided in form angles and in corners of column and beam boxes for chamfering of corners where shown on plans or directed.

The inside of forms shall be coated with an approved oil or thoroughly wetted. Oil shall be applied before reinforcement is placed.

Temporary openings for cleaning and inspection shall be provided at the base of vertical forms and at other places where they are necessary.

Removal of Forms and Shoring. Forms and shoring shall not be removed until the concrete is adequately set.

Upon removal of forms the contractor shall place adequate reshores to prevent injury to the concrete by construction loads. The contractor shall be responsible for safe practice in removing forms and shoring and for placing adequate reshores.

X. Reinforcing Steel.

Bars and rods shall be free from scale, oil, and structural defects, and shall be maintained so on the job.

Fabrication shall be accurately done to the dimensions shown on the plans. Stirrups and ties shall be bent around a pin having a diameter at least twice the bar thickness. Other bars shall be bent around a pin having a diameter at least 6 times the bar thickness. All bars shall be bent cold.

Supports. All steel shall be rigidly held in place with approved metal devices in such a manner that all steel will support the weight of the workmen without displacement.

Moisture Protection. On exterior exposed concrete no metal ties, chairs, or spacers shall remain within $\frac{3}{4}$ in. of the finished surface. All bars and rods shall have a minimum cover of 2 in. of concrete as shown on the plans.

Placing. All reinforcing steel within the limits of a day's pour shall be in place and firmly wired or clipped in sufficient time to permit inspection before concreting begins.

Bonding. Bars protruding for future bonding shall be protected as detailed on the plans.

XI. Mixing Concrete.

Concrete shall be mixed in a standard type of batch mixer with a drum speed of 200 to 225 peripheral feet per minute. Mixing time shall be 1 min. for batches of 1 cu. yd. or under, and shall be increased 15 sec. for each additional $\frac{1}{2}$ yd. or fraction thereof.

Retempered concrete shall not be allowed. Air-slaked or lumpy concrete shall not be used. The contents of the mixer shall be completely discharged before each new batch is loaded.

Ready-Mixed Concrete may be used, provided that the concrete produced conforms to these specifications and that the equipment and methods are in accordance with A.S.T.M. Specification C-94. *See "Data Book—Field."*

XII. Placing of Concrete.

Concrete shall be deposited, when practicable, in its final position without segregation, rehandling, or flowing.

When possible concreting shall be continuous until the section is complete.

Forms shall be clean before concrete is placed.

Concrete shall be spaded or vibrated to maximum subsidence, without segregation, and adjacent to forms and joints.

Reinforcing bars shall be shaken to insure bond with concrete.

Slabs and beam stems shall be placed in one operation.

Plumb bulkheads, when used as joints at the end of a day's work, shall be arranged at right angles to the plane of stress and in areas of minimum shear as directed by the engineer.

Concrete columns and walls shall set at least 3 hr. before the floor system is poured.

When stoppage of concreting operations occurs for any reason, construction joints shall be placed either horizontally or vertically as needed, provided with keys to resist shear, and dowels to develop bond, as directed by the engineer. Before concreting operations are resumed, the surface of the concrete shall be cut or chipped to remove all laitance and expose the aggregate. The surface of the concrete shall be thoroughly saturated and coated with a 1 : 2 mortar before the placing of the concrete is resumed.

Water Gain. Water accumulating during placing shall be removed. Concrete shall not be deposited in such accumulations.

Pumping and Conveying of concrete shall be done only by approval of the engineer and with equipment to insure a continuous flow without segregation.

XIII. Exposed Surfaces.

Interior. Imperfect surfaces where strength is not impaired may be patched and rubbed smooth with Carborundum brick.

Fins and projections shall be removed and the concrete surface affected thereby shall be rubbed smooth.

Exterior. Imperfect surfaces shall not be patched but shall be repaired by removal and replacement of the member.

Small voids shall be filled with 1 : 2 mortar pressed into holes and floated smooth.

Plastering and steel troweling of surfaces shall not be allowed.

Forms shall be fitted tightly so as to minimize fins. Joints shall be finished with beveled strips as directed by the engineer.

Construction joints in exterior work shall not be permitted except where shown on plans and then in accordance with details.

XIV. Curing Concrete.

After finishing, curing shall be done by keeping concrete moist for 1 week after placing. Floors and vertical surfaces may be sprayed with an approved preparation to retard evaporation of water if spraying is not objectionable because of subsequent finish. Curing operations shall begin as soon as the concrete has attained initial set.

Exposed exterior surfaces shall be kept moist for at least 1 week.

XV. Frost Protection.

The following rules are for the minimum requirements of protection and do not relieve the contractor from producing concrete which has not been weakened, or injured on the surface, by frost or freezing.

Cold weather shall be considered that period during the months of ____ to ____, and during this period concrete shall be given complete protection, except as stated below.

Full Protection shall consist of heating the materials, fully enclosing the concrete, and maintaining the temperature of the enclosure at not less than 60° F. for 7 days.

Aggregates and water shall be heated to not more than 175° F., and the concrete shall be not less than 70° F. or more than 90° F. when deposited.

Partial Protection. With the consent of the engineer, the contractor may, at his own risk, relax the above protection as follows: For partial protection, minimum temperatures shall be 40° F. on a falling thermometer and 35° F. on a rising thermometer. These rising and falling conditions shall be based on weather reports. The concrete shall be between 70° F. and 90° F. when placed.

For concrete pavements or mass concrete work in contact with the earth, the concrete surface shall be protected with straw, hay, or fabric for a minimum of 7 days. The earth or subgrade shall not be frozen when the concrete is placed thereon.

For reinforced-concrete building work, the surfaces shall be protected with hay or canvas and the story below shall be enclosed and heated to a minimum of 60° F. for at least 7 days.

Accelerating or Anti-Freeze Admixtures will not be permitted.

High-Early-Strength Cement shall be used only when specified or permitted by the engineer. All requirements of these specifications shall apply except time of curing, which shall be at 70° F. for 2 days or 60° F. for 3 days.

XVI. Floor Finishes.

Floor finishes shall be monolithic *or* bonded.

Monolithic Finish. Base concrete shall be very dry, containing 4 to 5 gal. of water per sack. The finish shall be 1 part cement and $2\frac{1}{2}$ parts sand. The sand shall be dried before using and the finish shall be mixed in a dry mixer.

Application. The finish shall be applied as a dry top dressing, $\frac{1}{8}$ in. to $\frac{1}{4}$ in. thick. It shall be thoroughly floated and troweled only long enough to make it smooth.

Bonded Finish. The slab shall be brought to a true surface, $\frac{3}{4}$ in. below the finished floor elevation, and it shall be roughened by being raked as it sets. At a later date when it is time to apply the finish, the slab shall be thoroughly cleaned by brushes and with a small jet from a high-pressure hose. All dirt shall be removed from crevices and depressions.

When the finish is ready to be placed, the floor shall be wet with 1 : 1 grout, and $\frac{3}{4}$ in. of granolithic finish shall be applied, as dry as is practicable for working. It shall be screeded, floated, and troweled to a smooth hard finish.

Granolithic Finish shall consist of 1 part cement, 1 part sand, and $1\frac{3}{4}$ parts of clean, sharp $\frac{1}{4}$-in. grit, mixed with about 3 gal. of water per bag of cement for machine mixing and a slump of 4 in. for hand mixing, the exact amount depending on the amount of water in the sand, grit, and slab below.

Machine Finish. (*Alternative for ramming and floating bonded finish by hand.*) The finish shall be screeded after ramming and the surface shall be rolled with rollers weighing not less than 20 lb. per in. of length for a diameter of 14 in. or less.

The rolled surface shall then be floated with machine floats; the machine operator shall add water in very small quantities a few inches ahead of the floater.

The floor shall be troweled twice by hand, unless it is a stuck-down floor, which shall be troweled only once.

Protection. All floor finishes shall be flooded within 24 hr. and covered with non-absorptive roofing paper of not less than 35 lb. weight per 100 sq. ft., lapped 2 in., to remain in place at least 2 weeks. The surface shall be protected from traffic by runways supported on smooth blocks. This method may be waived by the engineer in favor of spraying with an approved impervious membrane.

XVII. Built-in Fixtures.

The contractor shall furnish and install all bolts, pipe sleeves, inserts, and other fixtures, as shown on the plans, which are not set or formed by other trades and which are included in his contract.

XVIII. Approval of Materials.

Before use, samples of all materials shall be submitted for testing, and no material shall be used until it has been approved.

All inspected materials shall carry inspection approval marks or tags.

Manufacturer's Certificate. *Omit if laboratory tests are required.* Materials may be used if accompanied by manufacturer's certificate of compliance, pending any tests which may be made by the engineer. These certificates shall include quality and grading of aggregates and quality and type of cement and reinforcing steel.

Sampling. The engineer shall follow A.S.T.M. methods of sampling. *See "Data Book—Field."*

Laboratory Tests. Methods of testing shall be the latest revision of the following.

		Number of Tests
Aggregates	A.S.T.M. C-33	One set from each source and additional tests if there is any apparent change. Allow ____ C-33 tests.
Sulfate (soundness)	A.S.T.M. C-88	
Per cent of silt and clay	A.S.T.M. C-117	
Organic impurities	A.S.T.M. C-40	
Sieve analysis	A.S.T.M. C-136	
Surface moisture	A.S.T.M. C-70	
Fineness modulus	*See "Data Book—Field."*	
Cement (*Mill sampling preferred*)	A.S.T.M. C-77	One set for each 400 bbl.
Steel Reinforcing		
Bars and rods	A.S.T.M. A-15	One set for each 10 tons or each lot.
Wire fabric	A.S.T.M. A-82	Each 75,000 sq. ft. or each lot.
Concrete		
Compressive strength	A.S.T.M. C-39	4 preliminary tests for each mix design; 4 tests for each 250 cu. yd.; 1 cylinder broken at 7 days and 3 at 28 days.

Field Tests. *See Résumé of Field Tests in "Data Book—Field."*

		Number of Tests
Aggregates		
Sieve analysis	Check of gradation and fineness modulus.	Send samples to laboratory if there is any change. Supplement laboratory tests with these field tests. Conduct field tests daily and at any change.
Per cent silt and clay	Settlement or graduate bottle test, 5%	
Per cent organic matter	3% sodium hydroxide test, light amber	
Surface moisture	Fruit-jar test (pycnometer) or heating and drying	
Concrete		
Slump test		Continuously during concreting.
Unit weight test, to control density		Optional, daily.
Molding cylinders		4 for each 250 cu. yd. or each day's pour.
Temperature	Immersion thermometer	Continuously during cold-weather work.

XIX. Basis of Payment.

Specify that the contractor is to be paid at unit or *lump sum price called for in contract.*

Give work included and/or *excluded under this price.*

Give method of measurement.

If unit price, itemize price units.

If lump sum, itemize basis of payment for extra work including the following items: price per cubic yard of concrete (of each strength or mix designs) complete in place; price per ton for reinforcing steel complete in place.

Specify deductions will or *will not be allowed for volume occupied by sleeves, drain pipes, and other structures.*

STRUCTURAL STEEL—BUILDINGS

I. Scope of Work.

Work Included. This contract shall include furnishing and erection of the following material: column base plates, columns, beams, girders, bearing plates, loose lintels (see Section VII), trusses, anchor bolts for column bases, all field rivets and bolts, and sufficient bolts for erection equal in amount to 10% of the number of field rivets and other structural steel, as shown on the plans. For welded work, steel electrodes shall be furnished.

Work Not Included.

II. Material.

All steel required for this structure shall conform to the requirements of the latest edition of the A.S.T.M. specifications for structural grade.

All arc-welding electrodes shall conform to the requirements of the American Welding Society specifications for iron and steel arc-welding electrodes, latest edition.

III. Connections.

Shop connections shall be riveted *or* welded.

For field connections see Section VII.

IV. Workmanship.

Workmanship shall be in accordance with A.I.S.C. Specification for Fabrication and Erection and with the following outline.

Bearing surfaces shall be planed to true beds. Abutting surfaces shall be closely fitted.

All columns and bearing stiffeners shall be milled to give full bearing over the cross section. Column base plates 2 in. or less in thickness may be used without planing; plates between 2 in. and 4 in. in thickness may be straightened by pressing, or they may be planed; plates over 4 in. thick must be planed. It shall not be necessary to plane bottom surfaces of plates on grout beds.

Rivet holes shall be drilled or punched to exact location $\frac{1}{16}$ in. larger than the rivets, and shall register true upon erection. If the thickness of the material is not greater than the normal diameter of the rivet or bolt plus $\frac{1}{8}$ in., the holes may be punched. If it is greater, the holes shall be drilled or sub-punched and reamed. Large errors shall be cause for rejection. Small errors may be repaired by reaming if this course is approved by the engineer.

Holes for turned bolts shall be $\frac{1}{50}$ in. larger than the external diameter of the bolt. If bolts are inserted in the shop, the holes may be either drilled from solid or sub-punched and reamed. If the bolts are to be inserted in

the field, the holes shall be sub-punched in the shop and reamed in the field. All drilling or reaming for turned bolts shall be done after the parts to be connected are assembled.

All rivets, both field and shop, shall be power driven, shall fill the holes completely with full concentric heads, and shall be tight. Heads in abutting and bearing surfaces shall be countersunk and chipped flush. Heads in surfaces carrying brick walls shall be flattened to $\frac{3}{8}$ in.

Assembled parts shall be brought into close contact, and drift pins shall be used only for bringing members into position, not to enlarge or distort holes.

V. Welding. *Omit if not included.*

Welding in shop and field shall be done by operators who have been previously qualified by tests as prescribed in the American Welding Society Standard Qualification Procedure to perform the type of work required.

Equipment shall be of a type which will produce proper current so that the operator may produce satisfactory welds. The welding machine shall be of 200–400 ampere, 25–40 volt capacity.

Electrodes shall be of classification numbers E-6011, E-6012, E-6013, E-6020 and E-6030, and shall be suitable for positions and other conditions of intended use in accordance with the instruction with each container.

Field Welding shall be done by direct current.

Technique of Welding. The technique of welding employed, the appearance and quality of welds made, and the methods of correcting defective work shall conform to the American Welding Society Code for Arc Welding in Building Construction, Section 4, Workmanship.

Surfaces to be welded shall be free from loose scale, rust, grease, paint, and other foreign material except that mill scale which withstands vigorous wire brushing may remain. A light film of linseed oil may likewise be disregarded. Joint surfaces shall be free from fins and tears.

Temperature. No welding shall be done when the temperature of the base metal is lower than 0° F. At temperatures between 32° F. and 0° F. the surfaces of all areas within 3 in. of a point where a weld is started shall be heated until they are too hot to touch before welding is started.

Finished members shall be true to line and free from twists, bends, and open joints.

VI. Painting.

General. Paint shall be delivered to the shop and job in original sealed containers, which shall be clearly marked with the manufacturer's name and the identifying brand number or name. The paint shall be used as prepared by the manufacturer without thinning or other admixture.

All painting shall be done on dry surfaces, free from rust, scale, and grease. Steel shall be flame cleaned in the shop to remove mill scale. No painting shall be done in a temperature lower than 45° F. Surfaces in contact shall be cleaned by effective means but not painted, except that the contact surfaces of exposed exterior steel, such as tank supports, shall be painted.

Shop Paint. All steel, except where it is to be encased in concrete, shall receive one coat of shop paint. (Surfaces that are to be field welded shall not receive a shop coat.) The shop coat shall be ____. *See "Suggestions for Specifying Paints," p. 80.*

Field Paint. All field rivets, bolts, field welds, and serious abrasions to the shop coat shall be spot painted with the material used for the shop coat.

Steel encased in concrete shall not be painted.

Exposed Steel shall receive two coats of ____.

Interior Steel shall receive two coats of ____.

Spandrels faced with masonry subject to alkaline moisture shall receive one coat of ____.

Fill in blanks from "Suggestions for Specifying Paints," p. 81.

VII. Erection.

Erection shall include the setting of all columns and bases, and erection of all structural steel as called for under the contract for furnishing and delivery of structural steel, but shall not include the setting of loose lintels, which shall be set by the mason.

The contractor shall set column bases and beam plates, 12 in. by 12 in. and larger, on steel wedges or angle screeds, to accurate elevations approximately $1\frac{1}{2}$ in. clear of masonry; these will be grouted by the mason who will also set small beam plates. Wooden wedges shall not be used. All base plates over 20 in. shall be set on angle screeds. The contractor shall also set anchor bolts to be concreted in by the mason. All base plates over 30 in. in both directions shall have two 2-in. grout holes.

Field Connections. *These requirements will vary according to the type of structure and the requirements of codes. Specify in accordance with table below.*

Type of Connection	Riveted	Welded	Bolted	Remarks
Columns to columns	X			
Beams to columns	X			
Truss joints and cantilever splices	X			
Beams to beams			X	

Field errors shall not be corrected by burning except with the permission of the engineer.

Plumbing and Leveling. Steel surrounding elevator shafts shall be allowed a variation of 1 : 1,000 from plumb. All other steel shall be level or plumb within a tolerance of 1 : 500.

The contractor shall give his special attention to the handling of steel during construction, to avoid overloading green floor slabs; the instructions of the engineer shall be strictly adhered to, when criticisms are made in this regard.

VIII. Field Measurements. *Omit except in alterations or additions.*

The contractor shall make measurements in the field to verify or supplement dimensions shown on structural drawings, and he shall take the responsibility for the fit of the new steel to the existing work.

IX. Extra Steel.

The contractor shall include in his bid the cost of furnishing and erecting ____ tons of steel in addition to that shown and specified, and he shall state in his bid a unit price at which such of this steel as is not used shall be credited against the amount of his contract, provided that such changes as are made do not materially change the character of the work or involve scrapping or alterations of work already done.

X. Shop Drawings.

The contractor, immediately on the award of the contract, shall prepare shop drawings of all structural steel, based on the design drawings, for the approval of the architect and the structural engineer. These drawings shall give all the necessary information for the fabrication, erection, and painting of the structure, and shall be based on A.I.S.C. specifications.

Seat stiffeners shall not interfere with architectural clearances.

The following item is suggested to save the engineer's time in checking shop drawings.

Lithotracings of the engineer's drawings shall be obtained at the contractor's expense and shall be used for the erection plans.

Three sets of finally approved drawings shall be furnished, one for the architect, one for the engineer, and one for the shop inspector. The last set shall bear the engineer's O.K. No fabrication shall be conducted until this last set is in the hands of the shop inspector. Index sheets shall be furnished with all beam and column details as fast as the details come in.

XI. Ordering Steel.

No steel shall be ordered until the contractor receives a written authorization from the engineer, stating that the dimensions shown on the engineer's drawings are final.

XII. Tests.

Laboratory Tests. Methods of testing shall be according to the latest revision of the following.

		Number of Tests
Structural steel	A.S.T.M. A-7	Two tension tests from each melt. Two bend tests from each melt.
Structural rivet steel	A.S.T.M. A-141	One tension test from each melt. One bend from each melt.
Steel electrodes	A.S.T.M. A-233	Variable.

Field Tests.

Welding operators, *see American Welding Society, Standard Qualification Procedure.*

Check on manufacturer's certificates for paint.

XIII. Inspection.

The work shall be inspected in the shop and the field. The contractor shall give proper notice and allow full facilities for this inspection.

FIREPROOFING STRUCTURAL STEEL AND FLOOR ARCHES

All structural steel, except that which is incased in exterior brickwork, shall be inclosed in concrete and reinforced with wire mesh wrapping or with the approved soffit clip.

Haunch reinforcement of $\frac{1}{4}$ in. ϕ at 12 in. o.c. shall be provided for all steel beams 14 in. or over in depth.

The thickness of fireproofing shall be 2 in. for columns, 2 in. for beams, and 3 in. for foundation steel.

All steel to be protected by masonry shall be parged with $\frac{1}{2}$ in. of neat cement before the masonry work is begun.

Cinder Concrete Floor Arches. All floor arches and all fireproofing of steel shall be cinder concrete, mixed as follows: 1 part cement, 2 parts sand, and 5 parts cinders.

Mesh reinforcement shall be provided as shown on the plans.

Reinforcement details shall be as shown on the plans.

Cinders shall be clean and well-burned anthracite cinders, containing not less than 90% clinkers.

STEEL JOISTS

I. Scope.

Work Included. This contract shall include the furnishing and installing of all steel joists as shown on the plans. The reinforcement and metal lath for slab shall *or* shall not be furnished by the contractor but will be installed by others.

Work Not Included.

II. Materials.

All joists shall conform to the standard specifications of the Steel Joist Institute, latest edition.

Floor and ceiling lath shall be as shown on the plans and shall be painted or galvanized.

III. Workmanship.

Bearing shall be a minimum 6 in. on masonry and $2\frac{1}{2}$ in. on steel supports.

Bridging shall be of a rigid type, spaced 8 ft. 0 in. maximum on centers. A channel header shall be provided as shown on the plan.

Anchors. Joists on masonry shall have 3 in. ϕ wall anchors on alternate joists. All joists on steel supports shall be secured to the supports by $\frac{3}{16}$-in. rod anchors fastened over the flanges.

Painting. All joists shall have one coat of shop paint of ____. *See "Suggestions for Specifying Paint," p. 80.* The ends of all joists bearing on masonry shall be painted with one coat of asphalt paint after erection.

Erection. Steel joists shall be set true and level, and be so secured as to remain so during the pouring of the concrete.

Drawings. The contractor shall submit to the engineer for approval working drawings showing the spacing, size, and length of all joists, headers, etc.

WATERPROOFING OF CONCRETE AND MASONRY FOR HYDROSTATIC PRESSURE

I. Scope.

Work Included. This contract shall include all waterproofing by the plaster-coat or iron-coat method shown on the plans.

Work Not Included. This contract shall not include membrane waterproofing, integral waterproofing, or dampproofing.

II. Materials.

Water, sand, and cement shall be specified as under "Structural Concrete" specifications.

Plaster-Coat Method. The cement mortar shall consist of waterproofing compound, cement, and sand mixed in strict accordance with manufacturer's specifications. The waterproofing compound shall be of a type approved by the engineer.

Iron-Coat Method. The iron shall be clean, finely ground, and 98% pure iron. Chemicals may be added to accelerate the oxidation of the iron particles. The iron shall be of a type approved by the engineer.

III. Workmanship and Application.

Preparation of Surfaces. All surfaces to be waterproofed shall be examined by the contractor before the work is started. The engineer shall be notified of any defects in them. All surfaces to which waterproofing is applied shall first be thoroughly chipped and wire brushed, and then washed, first with diluted acid water and then with clear water, to present a new, fresh, and clean surface to which waterproofing will bond. For brick walls the general contractor shall rake out all joints to insure this bond further.

Hydrostatic Pressure shall be eliminated, while the waterproofing coat is being applied, by means of sumps, pumping, or relief holes.

Plaster-Coat Method. The waterproofing coat for floors shall consist of a plaster coat 1 in. thick, which shall be screeded and floated to a smooth, true, even surface, free from imperfections. The waterproofing coat for walls and ceilings shall consist of two coats. The scratch and finish coats shall be wood floated and steel troweled to a smooth, true, even surface, free from imperfections. The joints between the floor waterproofing and wall waterproofing shall be made at least 6 in. above the floor line, and to this end the scratch coat on the walls shall be carried down to floor level, and the finish coat shall be stopped approximately 6 in. above floor level, so that, where the floor waterproofing is applied, it shall be turned up with a cove base of at least 2-in. radius and 6-in. high. Interior columns and interior walls extending through floor slabs shall be waterproofed to a minimum height of 3 ft. 0 in. above floor level.

Iron-Coat Method. All surfaces shall receive as many brush coats of iron mixture as are required, but not less than two; proper time for complete oxidation shall be allowed between coats.

Floors shall be finished with a 1-in.-thick wearing surface of cement, sand, and iron, screeded, floated, and steel troweled to a smooth, even surface, free from imperfections. A cove shall be formed at the intersection of floors and walls. Walls shall receive a slush coat of iron, sand, and cement, followed by a scratch and a finish plaster coat. A good bond shall be provided by waterproofing carefully up to all hangers, inserts, and sleeves.

IV. Repairs.

If any leaks appear within a period of three years after the work is done, the contractor shall be obligated, at his own expense, to repair them by removing the coat at the point of leakage, roughing the concrete, and applying a new coat. He shall relieve the pressure while making repairs. The contractor shall not be responsible for any defects caused by settling or other structural causes.

V. The Contractor.

This work shall be performed by a firm or individual corporation which has made a specialty of this kind of waterproofing for at least five years and which can show at least three similar installations which have proved successful. *It is best to limit this work to about three firms well known for their qualifications in this line.*

VI. The Bond.

The waterproofing contractor shall furnish a bond, which shall be agreed upon in the contract, to insure the successful performance of his contract, and he shall agree that there is nothing in the above specification which will prevent such successful performance. The bond shall be for a period of five years.

VII. Tests.

The waterproofing job shall be subjected to a test of head, equal to that specified on the design drawings, and this head shall be obtained by natural or artificial means in order to effect a test of the qualities of the waterproofing. The cost of this test shall be borne by the general contractor.

WOODEN BUILDINGS

Do not use for slow-burning mill.

I. Scope of Work.

Work Included. This contract shall include the furnishing and installing of all wooden sheathing, joists, girders, columns, and trusses, including necessary bearing plates, connectors, bolts, beam hangers, and anchors, as shown or called for on the drawings.

Work Not Included. This contract shall not include finished mill work.

II. Material.

Wood. Lumber shall conform to the American Lumber Standards, "Simplified Practice Recommendations," R16-39. The grade shall conform to the grading rules of the manufacturer under whose rules the lumber is produced. Lumber shall bear the grade and trade mark of this association and a mark of mill identification.

Materials, when delivered to the site, shall be piled to insure proper drainage, ventilation, and protection from weather.

Specify grades and species to be used for various parts. See "Suggested Grades and Species for Timber Specifications," p. 69. These will vary according to material available, its cost, and the location of the project. See pp. 1-03 and 1-04 of "Data Book—Design."

Miscellaneous Metal. All material used for all metal connections shall conform to the latest specification of the A.S.T.M. for the material used.

III. Workmanship and Installation.

The sizes and spacing of timbers shall be as shown on the drawings.

All work shall be well braced, closely fitted, thoroughly spiked, accurately set, and rigidly secured in place. Joists and plates resting on masonry shall be leveled with slate shims.

Joists, rafters, and beams shall be set with the crown up, and where they rest on the masonry wall and are built in they shall be fire cut at the ends in the walls. Joists shall have at least a 4-in. bearing. Beams resting on walls shall have a bearing plate containing lug anchorage. Where one beam frames into another, standard beam hangers of duplex type shall be provided, unless it is otherwise shown.

Every third joist bearing on the walls shall be anchored to the wall with $\frac{1}{4}$ in. by $1\frac{1}{2}$ in. by 16 in. tee anchors, spiked to the joist and extending 8 in. into the wall. Joists parallel to the wall shall be anchored to it with strap anchors, at intervals of not more than 3 ft. 0 in., extending over and attached to three joists. The ends of all joists and beams shall be strapped together when they abut. The ends of lapped joists on bearings shall be securely spiked together.

No joists, beams, or rafters shall rest on any chimney. Cutting of a joist or beam for pipes shall be done only with the approval of the engineer.

All joists or rafters shall be bridged with lines of cross bridging as shown on the plans. The bridging shall be not less than $1\frac{1}{16}$-in. by $2\frac{5}{8}$-in. board nailed with two 8d nails at each end. Bottom ends shall not be nailed until after subfloors have been laid.

Columns shall not rest on wooden beams but shall have cast-iron lintels, or steel posts, caps, and base plates.

Holes for bolted connections shall be drilled straight and true $\frac{1}{16}$ in. larger than bolt size.

Timber connections, where they are shown on plans, shall be installed according to the instructions of the engineer.

IV. Drawings.

The contractor shall submit for approval framing plans showing sizes and spacing of beams and joists, details of hangers, bearing of beams, and working details of wood trusses.

Specify above depending on the extent of details shown on the design drawings.

V. Painting.

All exterior woodwork surfaces shall be cleaned, sanded, and dusted. After the priming coat has dried, not over 2 lb. cut of shellac or aluminum paint shall be applied to all knots, pitch, and sapwood; and all nail holes, cracks, open joints, and other defects shall be puttied.

All paint shall be applied on dry surfaces. No painting shall be done in freezing weather.

Paint shall be delivered in original unopened containers bearing manufacturer's labels, and shall be used as recommended by the manufacturer without being extended or modified except as directed or approved.

Give schedule of number of coats, and specify allowance, formula, or brands for interior wood finish, wood floors, and interior and exterior trim. *See "Suggestions for Specifying Paints," pp. 81 and 82.*

WOOD PRESERVATION AND PAINTING EXPOSED STRUCTURES

I. Scope.

Work Included. This contract includes the preservative treatment of wood as shown on plans *or* as specified to be treated.

II. Material.

Wood. *Specify species and grade to be treated. Specify type of preservative.*

Preservatives. Coal-tar creosote oil shall meet the requirements of the American Wood-Preservers' Association Standard Specification for Creosote 4f or U. S. Fed. Spec. TTW-556, latest edition.

Salts shall meet the requirements of the American Wood-Preservers' Association as follows:

Zinc chloride	Spec. 17a	Wolman salts (Tanalith)	Spec. 61b
Chromated zinc chloride	Spec. 60b	Zinc metal arsenite	Spec. 62b

III. Treatment Processes and Retention of Preservatives.

Pile Preservatives. All piles except fender piles shall be pressure-treated with creosote as follows:

1. Southern yellow pine piles	12 lb. empty cell	3. Southern yellow pine piles	20 lb. full cell
2. Douglas fir piles	12 lb. empty cell	4. Douglas fir piles	14 lb. full cell

Specify 1 and 2 for land and fresh water; 3 and 4, for salt water subject to marine borers.

Timber Preservatives. Creosote.

	Land or Fresh Water	Marine Water
Southern pine	12 lb. empty cell	16 lb. full cell
Douglas fir 5 in. or less in thickness	10 lb. empty cell	12 lb. full cell
Douglas fir more than 5 in. in thickness	8 lb. empty cell	12 lb. full cell

All Douglas fir 3 in. and over in thickness shall be incised before creosoting.

For retention of various members under several conditions of exposure use Fed. Spec. TT-W-571b as a guide.

Salt Treatments. To be used where wood is to be painted or is not in contact with ground.

Specify one of the following:

	Pounds Dry Salt per Cubic Foot		Pounds Dry Salt per Cubic Foot
Zinc chloride	1	Wolman salts	0.35
Chromated zinc chloride	0.75	Zinc metal arsenite	0.35

IV. Pressure Treatment Specifications.

	A.W.P.A. Spec.		A.W.P.A. Spec.
Southern pine piles	39 c*	Douglas fir piles	41b *
Southern pine timbers	53b (Tentative) *†	Douglas fir timbers	38b *†

* Creosote. † Salts.

V. Protection of Cut Surfaces and Pile Cut-offs.

Cut surfaces shall have 2 coats of hot creosote or 2 coats of concentrated salt solution.

Pile cut-offs shall have 2 successive coats of hot creosote followed with 50/50 creosote pitch compound.

VI. Painting Exposed Timber Work.

All exposed timber work to be painted shall if preserved be treated with ____ salts, not creosoted.

The following timber work shall be painted ____.

Timber specified to be painted shall be given 1 coat of ____ primer, and 2 coats of ____. See "Suggestions for Specifying Paints," pp. 81 and 82.

Painting shall be done only on dry surfaces. Painting shall not be done in freezing weather.

Paint shall be delivered in original unopened containers bearing manufacturer's labels and shall be used as recommended by the manufacturer without being extended or modified except as directed or approved.

SUGGESTED GRADES AND SPECIES FOR TIMBER SPECIFICATION

Adapted from Lumber Grade Use Guide
National Lumber Manufacturer's Association

Purpose	Tide-water Red Cypress	Douglas Fir Coast		Long Leaf Yellow Pine		Short Leaf Yellow Pine		Oak	Larch		Sitka Spruce	East-ern Spruce	Hem-lock
		*	†	*	†	*	†		*	†			
Docks													
Caps, rangers, stringers			1900		1900		1900			1900			
Cribs		200											
Bracing			1100				1100						
Floor systems (bridges or docks)													
Deck wearing		No. 1 Dim. Fir.		No. 1 85% Heart				No. 1 Struc-tural timber	No. 1				
Deck under	No. 1 boards					No. 1	Dense						
Floor beams			1900		1900								
Stadium seats (In addition, clear heart redwood, higher cost than group given in table)	Edge grain	218 Edge		Merch-ant-able edge grain									
Piles	√	√		√		√		√			√	√	√
Sheet piles	√	195		Merch-ant-able									
Fender piles								√ (Teak also or Green-heart)					
Trusses for bridges and buildings			2400, 2150, *or* 1900		2400, 2150, *or* 1900			2150		2150			
Buildings													
Beams and girders			1900		1900								
Posts and columns			1900		1900								
Studs			1700		1700								
Joists			1700		1700								

* Commercial grade.
† Stress grade. Vary stress grade as per design or design to stress grade called for.

See "Detailed Suggestions" following.

DETAILED SUGGESTIONS

P. & T. = posts and timbers
B. & S. = beams and stringers
J. & P. = joists and planks

C = compression parallel to grain
c = compression perpendicular to grain
f = extreme fiber stress in bending

DOUGLAS FIR[1]

Docks

Caps

Par. 200 No. 1 Timbers (390# c) * *or* Par. 210 Select Structural P. & T. (415# c).*

Stringers

Par. 218 Select Structural B. & S. (1900# f) * *or* Par. 218-a Dense Select Structural B. & S. (2150# f).*

Cribs

Par. 200 No. 1 Timbers (390# c).*

Bracing

Par. 214 Select Structural J. & P. (1900# f).*

Floor systems (bridges or docks)

Deck wearing 4 in. and thinner

Par. 195 No. 1 Dimension (for low-cost work).† Par. 214 Select Structural J. & P. (1900# f).* (Specify Dense, Par. 302, for wear.)

Decking 5 in. and thicker

Par. 200 No. 1 Timbers (390# c) * *or* Par. 218 Select Structural B. & S. (1900# f).* (Specify Dense, Par. 302, for wear.)

Decking laminated (on edge)

Par. 195 No. 1 Dimension.†

Piling

Sheet piles

Par. 195 No. 1 Dimension.†

Fenders and wales

Par. 195 No. 1 Dimension.† Par. 200 No. 1 Timbers (390# c) * *or* Par. 214 Select Structural J. & P (1900# f).* (Specify Dense, Par. 302, for hard wear.)

Stadium seats

Par. 113-b and Better V.G. Finish † *or* Par. 114 C.V.G. Finish.†

Bridge trusses (exposed members)

Compression and tension, 4 in. and thinner

Par. 214 Select Structural J. & P. (1900# f).*

Tension and compression, 5 in. and thicker

Par. 218 Select Structural B. & S. (1900# f).*

[1] These paragraph numbers refer to "Standard Grading and Dressing Rules of the West Coast Bureau of Lumber Grades and Inspection."

* Stress grade (structural). † Yard grade (commercial).

Buildings (heavy timber and masonry, joisted)

Posts

Par. 200 No. 1 Timbers (390# c) * *or* Par. 210 Select Structural P. & T. (415# c).*

Beams, joists, and purlins, 4 in. and thinner

Par. 195 No. 1 Dimension † *or* Par. 215 Framing and Joists (1450# f) * *or* Par. 214 Select Structural J. & P. (1900# f).*

Girders and headers, 5 in. and thicker

Par. 218 Select Structural B. & S. (1900# f) * *or* Par. 218-a Dense Select Structural B. & S. (2150# f).*

Roof trusses (covered), compression and tension members, 4 in. and thinner

Par. 215 Framing and Joists (1450# f) * *or* Par. 214 Select Structural J. & P. (1950# f).*

Roof trusses (covered), compression and tension members, 5 in. and thicker

Par. 219 B. & S. (1450# f) * *or* Par. 218 Select Structural B. & S. (1900# f).*

Roof decking, plank T & G, splined, shiplapped, or laminated

Par. 195 No. 1 Dimension † *or* Par. 214 Select Structural J. & P. (1900# f).*

SOUTHERN PINE, LONGLEAF, SHORTLEAF

Docks

Caps, cribs and stringers

Structural Square Edge and Sound Longleaf P. & T. (1450# C) 85% Heart * *or* Dense Structural Square Edge and Sound Shortleaf P. & T. (455# c) TREATED.*

Bracing

No. 1 Dimension Longleaf J. & P. (1700# f) 85% Heart * *or* No. 1 Dense Dimension Shortleaf J. & P. (1700# f) TREATED.*

Floor systems (bridges or docks)

Decking

No. 1 Structural Longleaf 85% Heart * *or* Dense No. 1 Structural Shortleaf P. & T. (455# c) TREATED.*

Decking laminated on edge

No. 1 Dimension Longleaf J. & P. (1700# f) 85% Heart * *or* No. 1 Dense Dimension Shortleaf J. & P. (1700# f) TREATED.*

Piling

Sheet piles

No. 1 Structural Longleaf P. & T. (1200# C) 85% Heart * *or* Dense No. 1 Structural Shortleaf P. & T. (1200# C) TREATED.*

Fenders and wales

No. 1 Structural Longleaf P. & T. (1200# C) 85% Heart * *or* Dense No. 1 Structural Shortleaf P. & T. (1200# C) TREATED.*

Stadium Seats

C Finish † *or* B and Better Finish, † both treated.

Bridge trusses (exposed members) treated

Compression and tension

Structural Square Edge and Sound Longleaf J. & P. or B. & S. (1900# f; 1450# C).* Dense Structural Square Edge and Sound Shortleaf J. & P. or B. & S. (1900# f; 1450# C).*

* Stress grade (structural). † Yard grade (commercial).

Bridge trusses (exposed members) untreated

Compression and tension

Structural Square Edge and Sound Longleaf 85% Heart J. & P.* or B. & S. (1900# f; 1450# C).*

Buildings (heavy timber and masonry, joisted)

Posts and columns

No. 1 Structural Longleaf P. & T. (1200# C) * *or* Dense No. 1 Structural Shortleaf P. & T. (1200# C) * *or* Structural Square Edge and Sound Longleaf P. & T. (1450# C) * *or* Dense Structural Square Edge and Sound Shortleaf P. & T. (1450# C).*

Beams and girders

No. 1 Structural Longleaf B. & S. (1700# f) * *or* Dense No. 1 Structural Shortleaf B. & S. (1700# f).* Structural Square Edge and Sound Longleaf B. & S. (1900# f) * *or* Dense Structural Square Edge and Sound Shortleaf B. & S. (1900# f).*

Joists and purlins

No. 1 Southern pine † *or* No. 1 Dimension Longleaf J. & P. (1700# f) * *or* No. 1 Dense Dimension Shortleaf J. & P. (1700# f).*

Roof trusses (covered)

2-in. members, compression and tension

No. 1 Dimension Longleaf J. & P. (1700# f; 1200# C) * *or* Dense Dimension Shortleaf J. & P. (1700# f; 1200# C).*

3-in. and 4-in. members, compression and tension

No. 1 Dimension Longleaf J. & P. (1700# f; 1200# C) * *or* No. 1 Shortleaf, medium grain, slope not exceeding 1 in 10 J. & P. (1450# f).†

Heavy plank and timbers, tension

Structural Square Edge and Sound Longleaf J. & P. or B. & S. (1900# f) * *or* Dense Structural Square Edge and Sound Shortleaf J. & P. or B. & S. (1900# f).* Merchantable Structural Longleaf J. & P. or B. & S. (1900# f) * *or* Prime Structural Longleaf J. & P. or B. & S. (2150# f) * *or* Dense Structural Shortleaf J. & P. or B. & S. (2150# f).* Select Structural Longleaf J. & P. or B. & S. (2400# f) * *or* Dense Select Structural Shortleaf J. & P. or B. & S. (2400# f).*

Plank roof decking

No. 1 Longleaf † *or* No. 1 Shortleaf Factory Flooring † *or* Standard Longleaf or Dense Standard Shortleaf Factory Flooring.†

TIDEWATER RED CYPRESS

Docks

Caps

Heart Grade P. & T. (1200# C).*

Stringers

Heart Grade B. & S. (1700# f) * *or* Heart Grade B. & S. (1300# f).*

Cribs

Heart Grade P. & T. (1200# c).*

Bracing

Heart Grade J. & P. (1300# f) * *or* No. 1 Heart Dimension.†

Floor systems (bridges or docks)

Deck wearing

Heart Grade J. & P. (1700# f) * *or* Heart Grade J. & P. (1300# f).*

* Stress grade (structural). † Yard grade (commercial).

Decking 4 in. and thinner
Heart Grade J. & P. (1700# f) * *or* Heart Grade J. & P. (1300# f).*

Decking 5 in. and thicker
Heart Grade B. & S. (1700# f) * *or* Heart Grade B. & S. (1300# f).*

Decking laminated
Heart Grade J. & P. (1700# f)* *or* No. 1 Heart Dimension.†

Piling

Sheet piles
Heart Grade J. & P. (1300# f).*

Fenders and wales
Heart Grade P. & T. (1450# c) * *or* Heart Grade P. & T. (1200# c).*

Stadium seats

Clear Heart Finish, No. 1 Heart Boards *or* (2-in.) No. 1 Heart Dimension.† (May specify edge grain against cupping.)

Bridge trusses (exposed)

Compression and tension members 4 in. and thinner
Heart Grade J. & P. (1700# f *or* 1300# f).*

Compression members 6 in. by 6 in. and larger
Heart Grade P. & T. (1450# c *or* 1200# c).*

Tension members 5 in. and thicker
Heart Grade B. & S. (1700# f *or* 1300# f).*

Buildings (heavy timber and masonry, joisted)

Posts and columns
1450# c *or* 1200# c Grade P. & T.*

Beams, joists, and purlins 4 in. and thinner
1700# f *or* 1300# f Grade J. & P.*

Girders and headers 5 in. and thicker
1700# f *or* 1300# f Grade B. & S.*

Roof trusses (covered)
Compression and tension members 4 in. and thinner
1700# f *or* 1300# f Grade J. & P.*

Compression members 6 in. by 6 in. and larger
1450# c *or* 1200# c Grade P. & T.*

Tension members 5 in. and thicker
1700# f *or* 1300# c Grade B. & S.*

Roof decking
1 in. boards
No. 1 Boards.†

2 in. and thicker
Grade (1300# f) * *or* No. 1 Dimension.†

* Stress grade (structural). † Yard grade (commercial).

CALIFORNIA REDWOOD

Docks

Caps
Select All-Heart Structural Timbers (1325# C).*

Stringers
Dense Select All-Heart Structural B. & S. (1700# f).*

Cribs
Select All-Heart Structural Timbers (1325# C).*

Bracing
Select All-Heart Structural Plank (1450# f).*

Floor systems (bridges or docks)

Decking, flat or laminated, 4 in.
Select All-Heart Structural Plank (1450# f).*

Decking, flat or laminated, 6 in.
Select All-Heart Structural B. & S. (1450# f).*

Piling

Sheet piles
Select All-Heart Structural Plank (1450# f) * *or* Bulkhead Structural Plank (1300# f).*

Fenders and wales
Select All-Heart Structural Stringers (1450# f).*

Piles
California Redwood Association's Round Timber Piling (A.S.T.M.).†

Stadium seats

Clear Heart Edge Grain Finish.†

Backs
Clear Heart Finish.†

Bridge trusses (exposed)

Compression, tension, and floor beams
Dense Select All-Heart Structural J. & P. or B. & S. (1700# f; 1450# C) 4 in. and 6 in. respectively.*

Buildings (heavy timber posts)

Select All-Heart Structural Timbers (1325# C).*

Girders, beams, purlins
Dense Select All-Heart Structural J. & P. or B. & S. (1700# f; 1450# C) 4 in. and 6 in. respectively.*

Roof trusses, compression and tension
Dense Select All-Heart Structural J. & P. or B. & S. (1750# f; 1450# C).*

Roof decking
No. 1 Heart Dimension.†

* Stress grade (structural). † Yard grade (commercial).

HARDWOODS

White Ash, Beech, Birch, Chestnut, Gum, Hickory, Maple, Oak, Pecan, and Tupelo

Docks

Caps
Common Dimension † *or* 1200# c Grade P. & T.*

Stringers
Common † *or* Select Dimension † *or* B. & S. 1450# f Grade * or 1700# f Grade.

Crib timbers
Sound Square Edge † *or* Common Timbers.†

Bracing
No. 1 Dimension † *or* 1450# f J. & P.*

Floor systems (bridges or docks)

Decking
No. 1 Dimension † *or* Bridge Plank Grade.†

Piling

Sheet piles
Sheet Piling Grade † *or* Common Timbers.†

Fenders, wales, and guard timbers
Common Dimension † *or* Common Timbers.†

Stadium seats

Heart White Oak and Chestnut B Finish † *or* No. 1 Dimension.†

Bridge trusses (exposed), white oak

Tension
1450# f, 1700# f, *or* 1900# f J. & P. or B. & S. Grades.*

Compression
1200# c *or* 1325# c P. & T. *or* 1900# f J. & P. or B. & S. Grades.*

LARCH, WESTERN

Docks

Caps
Structural P. & T. (1450# C) * *or* No. 1 Timbers.†

Stringers
Structural B. & S. (1900# f) * *or* Common Structural B. & S. (1450# f).*

Cribs
No. 1 Timbers, slope of grain 1 in 10 (1100# C).*

Bracing
No. 1 Dimension.†

* Stress grade (structural). † Yard grade (commercial).

Floor systems

Deck (wearing) and decking
Structural J. & P. (1900# f) * *or* Structural B. & S. (1900# f).*

Decking (laminated on edge)
No. 1 Dimension † *or* Structural J. & P. (1900# f).*

Piling

Sheet piles
No. 1 Dimension.†

Fenders and wales
No. 1 Timbers, slope of grain 1 in 10 (1100# C) * *or* Structural P. & T. (1900# C).*

Piles

A.S.T.M. D-25-37 Standard Specifications for Round Timber Piles, Class A, B, or C.

Bridge trusses, exposed members

4 in. and thinner, compression and tension
Structural J. & P. (1900# f).*

5 in. and thicker, compression
Structural P. & T. (1450# C).*

5 in. and thicker, tension
Structural B. & S. (1900# f).*

Buildings (heavy timber and masonry, joisted)

Posts
No. 1 Timbers † *or* Structural P. & T. (1450# C).*

Beams and purlins 2 in. to 4 in.
No. Dimension † *or* Structural J. & P. (1900# f).*

Girders and headers, 5 in. and up
No. 1 Timbers † *or* Structural B. & S. (1900# f).*

Roof trusses (covered)

4 in. and thinner, compression and tension
Structural J. & P. (1900# f).*

5 in. and thicker, compression and tension
Structural B. & S. (1900# f).*

Roof decking, 1-in. boards
No. 1 Dimension. 2 in. and $2\frac{1}{2}$ in.† Common Structural J. & P. (1450# f).*

* Stress grade (structural). † Yard grade (commercial).

RÉSUMÉ OF A.S.T.M. STANDARD SPECIFICATIONS FOR ROUND TIMBER PILES, D-25-37

Scope

1. Round timber piles to be used untreated, or treated by standard preservatives.

(*a*) For sawn timber as sheet piling, see "Grade Use Guide," National Lumber Manufacturers Association.

Kinds of Wood

2. (*a*) Specify kind *or* kinds desired, and the species acceptable for treatment. Commonly used species are the cedars, chestnut, cypress, Douglas fir (coast and mountain types), larch, lodgepole pine, Norway pine, black oak, bur oak, pin oak, post oak, red oak, white oak, willow oak, shortleaf and longleaf southern pine, spruce, and tamarack.

(*b*) Require differing species in separate lots.

Use Classification

3. There are three classes of timber piles, A, B, and C.

(*a*) *Class A.* Heavy railway bridges and trestles, etc. Minimum diameter of butt to carry 14-in.-wide caps.

(*b*) *Class B.* Docks, wharves, highway, and general construction. When timber is to be capped, butts must accommodate caps 12 in. wide.

(*c*) *Class C.* Cofferdams, in foundations completely submerged, falsework, and temporary uses.

Classes A and B

Quality

4. Free from red heart, decay, splits in treated piles, splits exceeding butt diameter (not treated), 180° spiral grain in any 20 ft. of length, unsound or numerous (clustered) knots or holes, or a shake exceeding $\frac{1}{3}$ the smallest diameter within its length, excessive turpentine scar or other impairment, as piling, of strength or durability.

Knots

5. Sound knots, not in clusters, shall not exceed $\frac{1}{3}$ the minimum diameter at the knot or 4-in. diameter for 50-ft. piles and less and in the upper half length of longer piles; single sound 5-in.-diameter knots but less than $\frac{1}{2}$ the diameter of the pile at that point are permissible between midlength and tip of piles exceeding 50 ft. in length.

General Requirements

6. (*a*) *Sound timber.* Exclude from Class A and Class B piles wind-felled, blighted, fire-killed, or unsound timber attacked by decay or insects; to be cut above ground swell.

(*b*) *Tip:* sound.

(*c*) *Butt:* sound. In cedar piles allow $1\frac{1}{2}$-in.-diameter pipe or stump rot hole.

(*d*) *Taper:* gradual from tip to 3 ft. below butt.

(*e*) *Surface:* trim and finish knots, lumps, and humps flush to taper surface. Square-cut sawn butt and tip, provided that pointed tip with 4-in. diameter (minimum) may be required.

Sapwood

7. (*a*) *Untreated:* minimum of sapwood, such that, in exposed work, the butt heart-ring shall be at least 80% of the butt diameter.

(*b*) *Treated:* maximum of sapwood, such that, in larch and Douglas fir, sapwood ring shall be not less than 1 in. at the butt, and in southern pine not less than $1\frac{1}{2}$ in. thick.

Peeled Piles

8. (*a*) *Treated:* remove all bark and all inner bark with minimum cutting and injury to sapwood.

(*b*) No pile shall retain before driving any outer bark or more than 20% of the inner bark; separated $\frac{3}{4}$ in. inner bark strips up to 8 in. long may be accepted.

Diameter

9. (*a*) The diameter of a pile shall be measured 3 ft. below the square-cut butt such that in any class not more than 25% of the piles of that diameter are not more than $\frac{1}{2}$ in. less.

(*b*) When not round, take $\frac{22}{7}$ of the circumference, or average the maximum and minimum diameters with calipers.

Length

10. Furnished cut to 2-ft. multiples, 16 to 40 ft.; over 40 ft., in multiples of 5 ft. Paint length legibly on each butt.

Straightness

11. Any line drawn from center of tip to butt center shall lie within the taper. Piles shall be free from short or reverse bends; crook shall not exceed $\frac{1}{2}$ the pile diameter at the middle of the bend.

Class C Piles

General Quality

12. Class C piles shall be sound and stand driving, shall be free from decay, bad knots, shakes, and like imperfections which will materially reduce strength, but they need not be peeled when driven untreated.

General requirements as to **13** (*a*) tip, (*b*) taper, (*c*) surface, **14** sapwood, **15** peeled piles, **17** length, and **18** straightness shall be identical with the corresponding provisions and requirements for Class A and Class B piles.

Diameter

16. Measurement and variations permissible for Class C piles shall be the same as for Class A and Class B piles, with sizes according to species as recommended in the accompanying table.

TABLE I

RECOMMENDED SIZES OF CLASS A, CLASS B, AND CLASS C PILES

Length of Pile	Classes A and B Piles				Class C Piles	
	Class A		Class B		(Vary in Size and Quality)	
	Minimum Tip	Diameter Range *	Minimum Tip	Diameter Range *	Minimum Tip	Diameter Range *
Douglas fir, larch, lodgepole pine, Norway pine, southern pine, spruce, and tamarack						
16′–38′, each 2′	10″ ϕ	14″–18″	8″ ϕ	12″–20″	8″ ϕ	12″–20″ †
40′, 45′, and 50′	9″ ϕ	14″–18″	7″ ϕ	12″–20″	6″ ϕ	12″–20″
55′, 60′, 65′, and 70′	8″ ϕ	14″–18″	7″ ϕ	13″–20″	6″ ϕ	12″–20″
75′, 80′, 85′, and 90′	7″ ϕ	14″–20″	6″ ϕ	13″–20″	6″ ϕ	12″–20″
95′, 100′, 105′, etc.	6″ ϕ	14″–20″	5″ ϕ	13″–20″	5″ ϕ	12″–20″
Black oak, bur oak, chestnut, cypress, pin oak, post oak, white oak, and willow oak						
16′–28′, each 2′	10″ ϕ	14″–18″	8″ ϕ	12″–18″	8″ ϕ	12″–20″ †
30′–40′, each 2′	9″ ϕ	14″–18″	8″ ϕ	13″–20″	8″ ϕ	12″–20″
45′, 50′, 55′, and up	8″ ϕ	14″–18″	7″ ϕ	13″–20″	6″ ϕ	12″–20″
Eastern red, northern white, and western red cedar						
16′–28′, each 2′	10″ ϕ	14″–22″	8″ ϕ	12″–22″	8″ ϕ	12″–22″ †
30′–40′, each 2′	9″ ϕ	14″–22″	8″ ϕ	13″–22″	8″ ϕ	12″–22″
45′, 50′, 55′, and up	8″ ϕ	14″–22″	7″ ϕ	13″–22″	7″ ϕ	12″–22″

* See Secs. 9 and 16, measurement of diameters of piles.
† For short Class C (20 ft. and less), 10 in. minimum diameter *at cut-off* is allowable.

SUGGESTIONS FOR SPECIFYING PAINTS

Explanation

The following methods of specifying are suggested:

1. The contractor shall include, in the amount of his bid, paint required by these specifications at the following cost per gallon for each type of usage. (*For instance, steel primer $1.50 per gallon.*) After the contract is let, the engineer will nominate the brand which he desires to use, and the contractor will be credited or debited with the amount overrun or underrun of the cost of this paint as compared with the allowance price. (*Gives engineer flexibility in selecting brands.*)

Using method 1, specify the type of paint under the following classifications: oil vehicle, synthetic resin, bitumastic, cement wash paint, etc. *This specification enables the contractor to arrive at a proper estimate for the cost of applying the paint, which varies considerably in the grades above-mentioned.*

2. The contractor shall supply the following brands for the purposes required in the schedule given below. *For instance, primer:*

Sherwin Williams Co., No. 79 Red Lead
Toch Bros., Inc., R.I.W. Brown Chromated Red Lead
Debevoise Co., "Dereka" Red Lead No. 505

(*This procedure is most advantageous for small jobs; it takes advantage of the advice and integrity of the manufacturer.*)

3. The contractor shall supply paint in accordance with standard specifications as per the following schedule. He shall notify the engineer's representative before the paint is mixed so that inspectors may be at hand during the mixing process and so that samples of materials may be taken for analysis. The paint shall be subject to analyses from samples taken at the site at random from painters' buckets as required by the engineer.

(*This requirement may be made for legal reasons on large public works. The objection to it is that the paint formulas have not been standardized.*)

SUGGESTIONS FOR SPECIFYING PAINTS

Purpose	No. of Coats	General Type	Formula	Suggested Manufacturers' Brands
Primer Metal	1	Red lead Allowance cost, $3.00–$3.25	Fed. Spec. TT-P-86	1. Toch Bros., Inc., R.I.W. Brown Chromated Red Lead 2. Sherwin-Williams Co., No. 79 Red Lead 3. Debevoise Co., Dereka Metal Paint Red No. 505, *or* No. 356 Pure Ready Mixed Red Lead 4. du Pont No. 750 Red Lead Primer *or* No. 800 Primer [1]
		Oxide Allowance cost, $1.50	Fed. Spec. TT-P-31a	1. Toch Bros., Inc., R.I.W. No. 159 Red Oxide 2. Debevoise Co., Quality Red *or* Brown Oxide

Note. Wherever Federal or Navy Specification is mentioned, the latest specification for that material will govern.

[1] Synthetic resin.

SUGGESTIONS FOR SPECIFYING PAINTS (*Continued*)

Purpose	No. of Coats	General Type	Formula	Suggested Manufacturers' Brands
		Yellow chromate Allowance cost, $2.25–$2.50	U.S.N. No. 84 Vehicle Formula 80	1. Toch Bros., Inc., R.I.W. Yellow Chrome Primer 2. Sherwin-Williams Co., Kromick Metal Primer (orange red) 3. Debevoise Co., Zinc Chromate Primer 4. du Pont, Zinc Chromate Primer No. 1614-724
Wood	1	White lead Allowance cost, $2.25–$2.50	Fed. Spec. TT-P-156 *or* TT-P-40, Type I & II	1. Toch Bros., Inc., R.I.W. Flex-Sicco 2. Sherwin-Williams Co., 450 Undercoater 3. Debevoise Co., Best Quality Exterior Primer (Lead and Titanium) 4. du Pont, No. 40 White
Finish				
Metal exterior (bridges)	1st field coat in addition to primer	Titanium, lead, zinc oxide Allowance cost, $2.25	Fed. Spec. TT-P-40	1. Toch Bros., Inc., R.I.W. Gray Tockolith 2. Sherwin-Williams Co., Metalastic, Selected Color 3. Debevoise Co., Dereka Metal Paint Maintenance Gray No. 518 [1] 4. du Pont, Dulux Metal Protective [1]
	2nd field coat	Carbon black Allowance cost, $2.00–$2.25	Fed. Spec. TT-P-61	1. Toch Bros., Inc., R.I.W. No. 49 Black or R.I.W. No. 1017 Black 2. Sherwin-Williams Co., Metalastic, Black 3. Debevoise Co., Dereka Metal Paint Black No. 501 4. du Pont Dulux Metal Protective Black [1]
		Or		
		Aluminum Allowance cost, $2.40–$2.60	2# Alum. plus E.T.T.V. 81a Vehicle [2]	1. Toch Bros., Inc., No. 1017 Aluminum 2. Sherwin-Williams Co., Silverbrite No. 429 3. Debevoise Co., Dereka Metal Paint Tank Aluminum No. 525 4. du Pont, Dulux Aluminum No. 220 [1]
Spandrels faced with masonry subject to alkaline moisture	1 heavy coat in addition to primer	Bitumastic coating (hot application) Allowance cost, $1.00		1. Toch Bros., Inc., R.I.W. Self-Healing Bridge Cement
Metal or wood interior	2 coats in addition to primer	Gray titanium base Allowance cost, $2.00–$2.25	Fed. Spec. TT-P-51a	1. Toch Bros., Inc., R.I.W. Semi-gloss or Interior Gloss 2. Sherwin-Williams Co., Save Lite tinted to color 3. Debevoise Co., Interior Eggshell Kiolite Gloss 4. du Pont, Mill White System
Wood floors	2 (no primer)	Varnish base	Fed. Spec. TT-S-176a	1. Toch Bros., Inc., Wood Floor Preservative 2. du Pont, Penetrating Wood Finish

[2] Navy specification.

SUGGESTIONS FOR SPECIFYING PAINTS (*Continued*)

Purpose	No. of Coats	General Type	Formula	Suggested Manufacturers' Brands
Wood exterior timber, untreated or salt treated *or* Exterior wood trim, guard rails, and posts (for base of guard rails, use Carbon Black, Fed. Spec. TT-P-61)	2 coats in addition to primer	Lead, zinc (1st finish) white Allowance cost, \$2.25–\$2.50	Fed. Spec. TT-P-40, Type II	1. Toch Bros., Inc., Flex-Sicco Primite 2. Sherwin-Williams Co., 450 Undercoater 3. Debevoise Co., Best Quality Exterior Primer 4. du Pont, Prepared Oil Paint
		Titanium, zinc, lead (2nd finish), each coat different color (light) Allowance cost, \$2.50	Fed. Spec. TT-P-40a, Type I	1. Toch Bros., Inc., Flex-Sicco 2. Sherwin-Williams Co., S.W.P. selected color 3. Debevoise Co., Character Outside Paint 4. du Pont, Prepared Oil Paint
		Aluminum Allowance cost, \$2.40–\$2.60	A.A.S.H.O. M-69	1. Toch Bros., Inc., No. 1017 Aluminum 2. Sherwin-Williams Co., Metalastic, Black 3. Debevoise Co., Dereka Metal Paint Tank Aluminum No. 525 4. du Pont, Dulux Aluminum No. 220 [1]
Rustic structure		Creosote oil stain		
Special metal In salt water, sewage, or fresh water	1 heavy coat primer	Bitumastic coating, cold application Allowance cost, \$1.00 *or*		1. Wailes Dove, Hermiston Corp., No. 50 2. Toch Bros., Inc., R.I.W. Marine Cement 3. Sherwin-Williams Co., Lyne-Kote S.P.C. No. 88 reduced to priming consistency
	and	Phenolic coating or Vinyl		1. du Pont, Submarine Primer No. 759 (not released)
	1 coat finish	Hot application Allowance cost, \$1.25		1. Toch Bros., Inc., R.I.W. Self-Healing Bridge Cement 2. Sherwin-Williams Co., Lyne Kote S.P.C. No. 88
Galvanized iron work Primer (finish as above). Zinc dust primers are preferred. If not available, clean and etch with Lithoform No. 2 (American Chemical & Paint Co., Ambler, Pa.)		Paint as above Allowance cost, \$2.50–\$3.25		1. Toch Bros., Inc., No. 708 Gray Galvanized Primer 2. Sherwin-Williams Co., G. & G. Industrial Primer 3. Debevoise Co., No. 555 Metallic Gray 4. du Pont, Galvanized Metal Primer No. 18960
Galvanizing	Hot, see A.S.T.M. Spec.	Hot dipped	A.S.T.M. A153-42T	
Concrete and masonry interiors	1 coat primer	Tung-oil base or approved synthetics Allowance cost, \$1.90–\$2.10		1. Toch Bros., Inc., Liquid Konkerit Primer 2. U. S. Gutta Percha Co., Barreled Sunlight Undercoat 3. Truscon Laboratories, Wallite No. 88 4. Sherwin-Williams Co., Save Lite Primer and Sealer 5. Debevoise Co., Wall Primer No. 336 6. du Pont, Concrete Primer Sealer

SUGGESTIONS FOR SPECIFYING PAINTS (*Continued*)

Purpose	No. of Coats	General Type	Formula	Suggested Manufacturers' Brands
	and 1 coat finish	Mill White heat-treated oils Allowance cost, $2.00–$2.50		1. Toch Bros., Inc., Tox-kote Mill White 2. U. S. Gutta Percha Co., Barreled Sunlight 3. Truscon Laboratories, Wallite No. 77 4. Sherwin-Williams Co., Save Lite Flat, Eg Shel Gloss 5. Debevoise Co., Concote White or Mill White Paints
Exterior concrete [3]	1 coat primer	Tung-oil base or approved synthetics Allowance cost, $2.10		1. Toch Bros., Inc., Liquid Konkerit Primer 2. Truscon Laboratories, Stonetex 3. Sherwin-Williams Co., Brick and Stucco Paint reduced 50% with S.W. Brick and Stucco Mixing Sealer 4. du Pont, Cement and Stucco Coating
	and 1 coat finish	Tung-oil base or approved synthetics Allowance cost, $2.50		1. Toch Bros., Inc., Liquid Konkerit Finish 2. Truscon Laboratories, Stonetex 3. Sherwin-Williams Co., Brick and Stucco Paint 4. du Pont, Cement and Stucco Coating
	or	Cement base, water vehicle Allowance cost, 14¢ per lb.		1. Master Builders Co., Mastertex 2. Medusa Portland Cement Co., Portland Cement Paint
Exterior cinder block	1	Casein paste alkyd resin Allowance cost, $1.50	Fed. Spec. TT-P-88	1. Toch Bros., Inc., Exterior Casein Paste Paint 2. Truscon Laboratories, Stonetex
Cement floor treatment				
Dust proofing (base for subsequent painting, cost 3¢ per sq. ft. applied)		Tung oil or approved synthetics Allowance cost, $1.50–$1.75		1. Toch Bros., Inc., R.I.W. Cement Filler 2. Truscon Laboratories, Granitex 3. Debevoise Co., No. 840 Floor Sealer
		Mineral gums and oils		1. Preservative Products Co.,[4] Esco Method
Dust proofing (suitable for office building wear, cost 1¢ per sq. ft. applied)		Magnesium and zinc fluosilicate		1. Toch Bros., Inc., Flintox 2. L. Sonneborn Sons, Inc., Lapidolith 3. Master Builders Co., Saniseal
Floor hardener (suitable for heavy duty, costs 2¢, 3½¢, 6¢ per sq. ft.)		Metallic surface integral Normal duty, 0.3 lb. per sq. ft. Heavy duty, 0.5 lb. per sq. ft. Static dissemination and spark proof, 1.2 lb. per sq. ft.		1. Toch Bros., Inc., R.I.W. Metallic Floor Hardener 2. Master Builders Co., Metalicon 3. Truscon Laboratories, Hurundum Aggregate

[3] No exterior concrete paints are known by author to be permanent.
[4] Work done by company.

SUGGESTIONS FOR SPECIFYING PAINTS (*Continued*)

Purpose	No. of Coats	General Type	Formula	Suggested Manufacturers' Brands
Acid-resisting paints		Allowance cost, $1.50–$3.25 Price controlled by particular acid-resisting paint for conditions		1. Debevoise Co., Debeloid Paints 2. du Pont, Acid and Alkali Resisting Finish
Pipe—sewer and water				
C.I., exposed				
Shop, inside and outside of pipe	1	Coal-tar pitch varnish, hot dip	Fed. Spec. WW-P-421 *or* A.W.W.A. Spec. 1908	
Field, outside of pipe only	1	Aluminum bitumastic		
C.I., in trenches				
Shop, inside and outside of pipe	1	Coal-tar pitch varnish, hot dip	Fed. Spec. WW-P-421 *or* A.W.W.A. Spec. 1908	
Field	None			
C.I., for interior plumbing	None			
Steel, exposed				
Shop, outside of pipe	1	Red lead primer	A.W.W.A. Spec. 7A6	
Shop, inside of pipe	1	Coal-tar primer	A.W.W.A. Spec. 7A6	
	1	Hot coal-tar enamel	A.W.W.A. Spec. 7A6	
Field, outside	1	Red lead primer	A.W.W.A. Spec. 7A6	
	1	Aluminum	A.W.W.A. Spec. 7A6	
Steel, in trenches				
Shop, inside and outside of pipe	1	Coal-tar primer	A.W.W.A. Spec. 7A6	
	1	Hot coal-tar enamel	A.W.W.A. Spec. 7A6	
Shop, outside additional protection		Asbestos felt wrapper and 1 coat of water-resistant whitewash	A.W.W.A. Spec. 7A6	
Galvanizing steel pipe or W.I. corrosion protection	See specifications		A.S.T.M. Spec. A-120-42	
Machinery and pipe enamel for medium heat up to 200° F., black, in colors	2 in addition to primer	Heat-treated oil vehicle Allowance cost, $2.25–$2.50		1. Debevoise Co., Dado and Machinery Enamels 2. Toch Bros., Inc., Pipe and Machinery Enamel: first coat, semi-gloss; finish, gloss
Pavement stripes	1	Chrome yellow or white	Fed. Spec. TT-P-115	1. Toch Bros., Inc., R.I.W. White or Chrome Yellow Traffic Paint 2. du Pont, Traffic White
	1	Carbon black (non-reflective)	Fed. Spec. TT-P-61	1. Toch Bros., Inc., R.I.W. Black Ready-Mix Paint
	1	Glass sphere reflective paint[5] (white or yellow)	U.S. Eng. T-12-90	
Signs	1	Carbon black	Fed. Spec. TT-P-61	1. Toch Bros., Inc., R.I.W. Black Ready-Mix Paint 2. du Pont, Bulletin Color
	1	Chrome yellow	Fed. Spec. TT-P-53	1. Toch Bros., Inc., R.I.W. Highway Yellow 2. du Pont, Bulletin Color

[5] Making traffic paint reflective by embedding glass beads in pigment is a patented process; specifications to be obtained from patentee.

SUGGESTIONS FOR SPECIFYING PAINTS (*Continued*)

Purpose	No. of Coats	General Type	Formula	Suggested Manufacturers' Brands
	1	White, outside (titanium, lead, zinc oxide)	Fed. Spec. TT-P-40	1. Toch Bros., Inc., Ready Mix White
	1	Outdoor yellow enamel	U.S. Dept. of Agriculture, Forest Service, Natl. Bureau of Standards Spec.	1. Toch Bros., Inc., R.I.W. Toxkote Exterior Enamel
	1	Exterior white enamel	U.S. Treasury, Procurement Division Spec. 359	1. Toch Bros., Inc., R.I.W. Toxkote Exterior Enamel 2. du Pont, Bulletin Color
	1	Outdoor black enamel	Fed. Spec. TT-E-521	1. Toch Bros., Inc., R.I.W. Toxkote Exterior Enamel 2. du Pont, Bulletin Color
	1	Reflectorized coating systems	War Dept. Spec.	1. Patented
Galvanizing wire cable, fittings, and exposed metal	2	Hot-dipped zinc coating	A.S.T.M. Desig. A 123. A.A.S.H.O. Desig. M-30	
Swimming Pools				
Preparation		Wash with 10% muriatic acid		
Primer	1			1. Toch Bros., Inc., No. 6632 R.I.W. Toxkote Enamel (reduced 25% with turpentine)
Finish	1			1. Toch Bros., Inc., No. 6632 R.I.W. Toxkote Enamel (without reduction)

III

AIRPORTS, ROADS, AND RAILROADS

OUTLINE FOR A COMPLETE ROAD SPECIFICATION

I. Items to Include:

Title page.
Table of contents.
Invitation to bidders. (*See p. 1.*)
Proposal forms. (*See pp. 4 and 7.*)
Contract forms. (*See pp. 10 and 13.*)
Performance bond.
General conditions. (*See p. 18.*)
Special conditions below.
Detail specifications.

Preparation of site. (*See p. 29.*)
Grading. (*See p. 89.*)
Drainage. (*See pp. 157 to 160 incl.*)
Base course. (*See pp. 93 to 101 incl.*)
Paving. (*See pp. 102 to 130 incl.*)
Roadway structures. (*See p. 134.*)
Bridges. (*See p. 139.*)
Lighting.
Landscaping.
Seeding. (*See p. 132.*)
Any other work called for by plans.

II. Special Conditions. *See also p. 26.*

Traffic Control. The contractor shall, where necessary, provide and maintain access to and from all properties along the line of his work. The contractor shall also provide temporary bypasses and bridges and maintain them in a safe and usable condition whenever, in the opinion of the engineer, detouring of traffic to parallel routes cannot be done without hardship or excessive increase in travel by the public.

Where single-lane bypasses are provided, the contractor shall furnish signalmen to control traffic operations and minimize delays.

When directed by the engineer, the contractor shall perform excavating, paving, and other operations on one side of the road at a time to allow for the movement of traffic.

Safeguards. The contractor shall provide, erect, and maintain adequate barricades, warning signs, and lights at all excavations, closures, detours, points of danger, and completed pavements.

Opening of Sections of Road to Traffic. Completed pavement shall be opened to traffic when and where directed by the engineer, but such opening shall not constitute final acceptance of the work. Maintenance shall be at contractor's expense.

Construction Stakes. The engineer will set sufficient points to establish the alignment and grade. The contractor shall furnish free of charge all materials and labor necessary to assist the engineer in setting line and grade stakes. The contractor shall be responsible for preserving all stakes and marks.

Restoration of Surfaces. The contractor shall not allow any openings to be made except on authorized permit. Repair work involved in restoring surfaces shall be performed by the contractor at the expense of the party making the opening.

Blasting. All work with explosives shall be done in such a manner as not to endanger life or property. All storage places for explosives and inflammable materials shall be clearly marked *Dangerous*. The method of storing and handling explosive and inflammable materials shall conform with all federal, state, and local laws, bylaws, and regulations.

Tests and Sampling. The contractor shall provide labor, material, and transportation for the tests and sampling. The owner will provide expert services and testing and sampling equipment.

Specify that the contractor provide a laboratory building suitable as to size, light, heat, and water for the type of testing called for in the specification.

Add clauses for special requirements of the particular project.

GRADING FOR ROADS, AIRPORTS, AND RAILROADS

I. Scope of Work.

Construction of embankments and grading shall be in accordance with the plans and specifications. (*Specify any exceptions.*)

II. Stripping and Spreading of Topsoil.

All topsoil shall be stripped from areas to be paved, excavated, or filled, and from other areas as shown on plans. *If possible, specify depth of topsoil to be stripped.* Topsoil shall be stored in stockpiles, the location of which shall be selected by the engineer *or* as shown on plans.

On areas shown on plans to receive topsoil, the subgrade shall be scarified to a depth of 2 in. for the bonding of the topsoil with the subsoil. Hand shoveling and raking will be required, followed by rolling with one pass of a flat roller weighing not more than 100 lb. per lin. ft. and not less than 25 lb. per lin. ft. On slopes steeper than 4 : 1 the topsoil shall be rammed or tamped in place as directed by the engineer.

Areas to be sodded shall receive 3 in. of topsoil; areas to be seeded shall receive 6 in. of topsoil.

III. Excavation.

Excavation shall conform to limits indicated on the plans or specified herein.

Excavation shall not be made below grade except where rock or stone masonry is encountered or removal of unstable material is directed by the engineer.

Material removed below grade shall be replaced with approved material thoroughly compacted or as otherwise directed by the engineer.

Excavated material suitable for embankments or fills shall be stored, if required, to minimize the use of borrow.

Borrow. Where required to complete the embankment or fill, the contractor shall provide the necessary additional material. The source and quality of borrow material shall be approved by the engineer.

The contractor shall give the engineer at least 5 days' notice before removing borrow material from any approved borrow pit.

Rock Excavation. Rock excavation shall include removal of ledge rock, concrete or masonry structures which require drilling or blasting, and boulders larger than ____ cu. yd. (*varies with size of equipment used*) in volume.

Ledge rock, boulders, concrete or masonry structures shall be removed to a minimum depth of ____ in. below subgrade and backfilled with approved material thoroughly compacted.

Rock shall be conserved if required for purposes shown on the plans, or for any other purpose, as the engineer may direct.

Drainage. Spring or seepage water encountered shall be reported to the engineer if drainage is not provided for by the plans. The contractor shall keep the excavation free from water at all times by pumping or otherwise.

Excess or Disapproved Excavated Material shall be disposed of as directed by the engineer.

IV. Embankment and Fills.

Fills shall not be started until the area has been inspected and approved by the engineer.

Embankment and fill material shall be free from frost, stumps, trees, roots, sod, or muck. Only approved material from excavation or borrow pits shall be used. Material shall not be placed on frozen ground.

Preparing Ground Surface. Sloped surfaces steeper than 4 : 1 shall be scarified or stepped and compacted to provide bond with new material.

When existing roadways are to be covered with less than 1 ft. of fill the surface shall be scarified and compacted to the same density as adjacent areas.

When fill is to be placed over wet ground that will not support the weight of trucks or other equipment, the lower part of the fill shall be made with sand, gravel, or other selected material deposited in a blanket layer no deeper than necessary to support the operating equipment. Top 9 in. of blanket layer shall be compacted to required density before subsequent layers are placed.

Construction Methods. Excavated material shall be so handled, conserved, stored, and placed as to have the least desirable material at the bottom of embankments, grading up to the best material at the top.

Sandy Soils shall be placed in 4-in. to 6-in. layers and compacted with caterpillar tractor, tamping roller, or smooth-wheel roller weighing 8 to 10 tons.

Clay Soils shall be placed in 8-in. maximum layers and compacted with light tamping roller.

Glacial Till shall be placed in 8-in. maximum layers and compacted with heavy tamping roller.

The contractor may use other equipment if approved.

Places inaccessible to roller shall be compacted with mechanical or hand tampers.

Final rolling of top layer shall be with a smooth-wheel power roller weighing 8 to 10 tons.

Stones in earth fill shall be well distributed. No stones over 4 in. in diameter shall be within 12 in. of finished subgrade.

Each layer shall be free of ruts and shall meet compaction requirements before succeeding layer is placed. Layers shall be maintained with crown or slope to provide drainage and prevent erosion.

At least the top 6 in. of pavement subgrade shall be of selected granular material.

Rock Fill. In embankments or fills, rock may be any maximum size if uniformly graded. All voids shall be completely filled with fine material and conpacted to form a dense mass.

The fill for a thickness of at least 2 ft. below the finished subgrade shall be selected earth material placed and compacted in layers to the degree specified below.

Operation of Equipment shall be distributed to avoid rutting and unequal compaction.

Protection of Structures. Culverts, headwalls, and other structures shall be constructed before fill is placed. Fill around culverts, headwalls, or other structures shall be carefully and symmetrically placed in 6-in. to 8-in. layers and shall be compacted to the degree specified below.

V. Compaction Requirements. *(Specify one of the following.)*

Test-Controlled Compaction. *(Use for large or important projects.)* In construction of embankments and preparation of subgrades, all soils shall be compacted to 90% of maximum density at optimum moisture as determined by A.S.T.M. D-698, except that soils for a depth of 9 in. below pavement subgrades in both cuts and embankments shall be compacted to not less than 95%.

Soils which weigh less than 100 lb. per cu. ft. shall be wasted or mixed with heavier soils to obtain the required weight.

When material varies from optimum moisture content, it shall be treated as follows:

When wet it shall be drained or worked until optimum moisture content is attained. When dry it shall be sprinkled with water and mixed until optimum moisture content is attained.

Practical Control. *(Use only where test control is not warranted by size or importance of project.)* In construction of embankments and preparation of subgrades the soil shall be compacted with approved equipment. The soil shall be treated and worked so as to be damp but not wet.

If tamping rollers are used, 10 or more passes will be required on each layer as directed by the engineer.

When smooth-wheel power rollers weighing 8 to 10 tons are approved and used, the layer shall be rolled until no weaving or creeping appears ahead of the roller.

VI. Subgrade Preparation. *(Specify one of the following.)*

In cut areas the subgrade shall be scarified and compacted to 95% of maximum unit weight at optimum moisture for a depth of at least 6 in. See Paragraph V above. *Or*

In cut areas the subgrade shall be scarified and compacted for a depth of at least 6 in. by rolling with a 3-wheel power roller weighing 8 to 10 tons.

Rough subgrades shall be formed and compacted in accordance with the plans within a tolerance of $1\frac{1}{2}$ in.

Soft areas in subgrade shall be reinforced with crushed stone, gravel, or telford as directed by the engineer. These areas shall be drained as directed by the engineer.

Final rolling of subgrade shall be with 3-wheel power rollers weighing 8 to 10 tons.

Rough subgrades, including slopes and ditches, shall be formed and maintained to provide proper drainage.

VII. Fine Grading of Subgrade. *(This item may be included as part of the contract covering the construction of the base course or pavement.)*

Rough subgrade shall be cleaned of all loose or foreign material and reshaped if rutted. Approved material shall be added to meet required grade. Shaping and compacting shall be done with blade graders and a 3-wheel power roller weighing 8 to 10 tons. Soft spots shall be reinforced and drained as specified in Paragraph VI above.

Tolerances. Finished surface shall be smooth and even and shall not vary more than $\frac{3}{8}$ in. in 10 ft. from true profile and cross section or more than $\frac{1}{2}$ in. from true elevation.

VIII. Shoulder Construction.

Where trench method of construction is to be used for pavement, sides shall be cut to vertical face at proposed edge of pavement.

Shoulder material shall be placed in uniform layers for full width and thickness. Each layer shall be compacted by rolling. Roller shall overlap shoulder when rolling both base course and pavement. Finished shoulder shall be firm against pavement.

Drainage shall be provided for pavement subgrade at low points.

IX. Finishing Slopes and Surfaces.

All areas shall be finished to smooth, compact surfaces in conformity with the plans.

Slopes. Blade grader or scraper finish will *or* will not be allowed. Hand shovel finish will *or* will not be required.

Shoulders, Ditches, and Gutters. Hand shovel and raking finish will be required.

Maintenance. Finished work shall be drained and maintained in accordance with the plans until final acceptance.

X. Tests. *(For test-controlled compaction see Paragraph V above.)*

The contractor shall provide labor, material, and transportation for the following tests and sampling. The engineer shall provide expert services and testing and sampling equipment.

Sampling. The engineer shall follow A.S.T.M. methods of sampling. *(See "Data Book—Field.")*

Laboratory Tests. Methods of test shall be the latest revision of the following:

		Number of Tests
Dry weights when compacted at optimum moisture of various types of soil	A.S.T.M. D-698	As required to provide a control for moisture and density field tests.

Field Tests. (*See "Data Book—Field."*)

	Number of Tests
Moisture content Dry weight of compacted soil	At least one for every 500 sq. yd. on each layer, or sufficient number of tests to insure thorough and uniform compaction. Additional tests if soil or moisture conditions change.

Auger borings shall be made as directed by the engineer when there are indications of poor material underlying subgrade.

XI. Basis of Payment. (*Specify that the contractor be paid at unit or lump sum price called for in the contract.*)

Give work included and excluded under this price or *give method of measurement.*

If unit price, itemize price units.

If lump sum, itemize basis of payment for extra work including the following items:

Price per cubic yard for earth excavation.

Price per cubic yard for rock excavation.

Price per cubic yard for borrow.

Price per cubic yard per 100-ft. station for overhaul.

Price per cubic yard for placing topsoil.

Price per square foot for sodding.

GRAVEL BASE OR SUB-BASE COURSE

Simple control. For strengthening subgrades and frost protection. Use only as base course under a pavement.

I. Scope of Work.

II. Description.

This work shall consist of constructing a sub-base course of gravel, compacted in layers of 4-in. maximum thickness, upon a previously prepared subgrade in accordance with the plans and specifications.

III. Materials.

Gravel shall consist of a natural or artificial mixture of hard, durable pebbles, rock fragments, and soil binder, free from soft particles and excess clay, and conforming to the following gradation:

Sieve Designation	Percentage by Weight Passing Square-Mesh Sieves
A size sieve equal to $\frac{1}{3}$ the depth of base course	100
$\frac{1}{4}$ in.	25–60
No. 200	0–10

IV. Construction Methods.

Subgrade shall be graded to proper elevation and cross section and rolled to an even, firm foundation, without ruts or soft yielding places.

Placing and Spreading shall be in uniform layers, without segregation of size, to such loose depth that when compacted the layer will have the required thickness.

Mixing. The gravel shall be mixed with blade graders or other equipment until a uniform mixture is obtained.

Rolling. Each layer shall be compacted by rolling with a 3-wheel power roller weighing at least 10 tons. Alternate blading and rolling shall be required as directed until a smooth, even, and uniformly compacted course is obtained.

Maintenance. The surface of any layer shall be maintained in its finished condition until the succeeding layer is placed. The base shall be properly drained at all times.

V. Approval of Materials.

Before use, samples of all materials shall be submitted for approval.

VI. Tests.

Sampling. The engineer shall follow A.S.T.M. methods of sampling. *See "Data Book—Field."*

Laboratory Tests. Methods of test shall be the latest revision of the following:

	Number of Tests
Gravel: Sieve analysis A.S.T.M. C-136	One from each sample from each source submitted in advance.

Field Tests. *See "Data Book—Field."* Sieve analysis shall be made daily on mixed gravel. Additional sieve analysis shall be performed for any apparent change.

VII. Basis of Payment.

Specify that the contractor be paid at unit or lump sum price called for in the contract.

Give work included and/or excluded under this price.

Give method of measurement.

If unit price, itemize price units.

If lump sum, itemize basis of payment for extra work, including the following item: price per cubic yard for additional base course complete in place.

MECHANICALLY STABILIZED GRAVEL BASE COURSE

Scientific control. For base course or low-type surface when surface treated. Other aggregates may be substituted for gravel.

I. Scope of Work.

II. Description.

This work shall consist of constructing a base course of graded gravel material, compacted in layers of 4-in. maximum thickness, upon a previously prepared subgrade or sub-base to a finished thickness of ____ in. in accordance with the plans and specifications.

III. Materials.

Graded Gravel. Graded gravel shall consist of a natural or artificial mixture of hard, durable particles of coarse aggregate and soil binder. The material shall be relatively free from soft or decomposed particles and excess clay, and shall be uniformly graded so that it can be compacted into a hard, dense mass. The natural or processed mixture shall conform to the gradation given in the table below.

Specify one of the following gradations in accordance with type of gravel available or required to be used.

REQUIREMENTS FOR GRADING AGGREGATE

Sieve Designation	Percentage by Weight Passing Square-Mesh Sieves		
	2 in. Maximum	*1½ in. Maximum*	*1 in. Maximum*
2 in.	100		
1½ in.	.....	100	
1 in.	55–85	70–95	100
¾ in.	50–80	55–85	70–100
No. 4	30–60	30–60	35–65
No. 40	10–30	10–30	15–30
No. 200	3–10	3–12	5–15
Clay (−0.005 mm.)	0–3	0–3	0–3

Suitable material shall be added if necessary to make natural gravel conform to the required gradation.

Additional Control. The amount of material passing the No. 200 sieve shall be less than one-half the amount passing the No. 40 sieve. The portion passing the No. 40 sieve shall have a liquid limit of not more than 25 by A.S.T.M. D-423.

For soils where there is greater than 6-in. frost penetration the plasticity index A.S.T.M. D-424 shall be 0. Elsewhere it shall be less than 4.

The coarse aggregate retained on a No. 4 sieve shall have a percentage of wear by the Los Angeles abrasion machine test of not more than 50.

IV. Construction Methods.

Preparation of Previously Constructed Subgrade or Sub-Base. All loose or foreign material shall be removed.

Any ruts or soft yielding places that appear on the subgrade or sub-base shall be corrected and rolled until firm.

Necessary subgrade or sub-base material shall be added to conform to proper grade and cross section.

The subgrade or sub-base shall be rolled to an even firm foundation.

Weather Limitations. Base course shall not be constructed during freezing weather or on a wet or frozen subgrade or sub-base.

Multiple Courses. When it is necessary to construct the base in more than one layer to conform to the required finished thickness each layer shall be constructed as described below.

Operation in Pits. All work involved in clearing and stripping pits and handling disapproved material encountered shall be performed by the contractor at his own expense. The base material shall be obtained from pits or sources that have been approved. The material in the pits shall be excavated and handled in such a manner that a uniform and satisfactory product shall be secured.

The contractor shall notify the engineer at least 5 days before opening any approved pit.

Placing and Spreading. The material shall be deposited and spread in lanes in a uniform layer and without segregation of size to such loose depth that when compacted, making due allowance for any admixture that is to be blended, the layer will have the required thickness.

Mixing. In the event that the constituents of the material which has been spread are segregated and lack the intimacy of mixture of the coarse and fine particles, the material shall be mixed with harrows, blades, rotary tillers, or other approved equipment until a thoroughly uniform mixture is obtained.

Blading and Blending Admixture. When the required amount of admixture material has been spread, it shall be thoroughly mixed and blended by means of approved graders or mixing equipment. The mixing shall continue until the mixture is uniform throughout. Water in the amount directed by the engineer shall be uniformly applied before and during the mixing operations, in order to accomplish more effective mixing. When the mixing and blending have been completed, the mixture shall be spread to a uniform depth sufficient to give the required thickness of layer when compacted.

Rolling. Immediately after final spreading, each layer shall be compacted for the full width and depth by rolling with a pneumatic roller (*preferable if obtainable*), or a 3-wheel power roller weighing at least 10 tons, or any other approved compacting equipment. Alternate blading and rolling shall be required as directed, to obtain a smooth, even, and uniformly compacted course.

Places inaccessible to roller shall be compacted with mechanical *or* hand tampers.

Compaction Control. The gravel base shall be compacted to not less than 95% of maximum density at optimum moisture content as determined by A.S.T.M. Test D-698 (*Modified A.A.S.H.O. for runways*).

When the material varies from optimum moisture content it shall be treated as follows:

When too wet it shall be drained or worked. When too dry, it shall be moistened.

Tolerances. Surface shall be true to established grade. Thickness shall not be less than $\frac{1}{4}$ in. from that required for the layer being constructed. Surface shall not vary more than $\frac{3}{8}$ in. in 10 ft. from true profile and cross section ($\frac{1}{4}$ *in. for runways*).

Reconstructing Damaged Base Course. Should the subgrade or sub-base at any time become soft or churned up with the base-course material, the contractor shall, without additional compensation, remove the mixture from the affected portion, reshape and compact the subgrade or sub-base, and replace the removed section in accordance with the foregoing requirements.

Maintenance and Protection of Base Course. The surface of any layer shall be maintained in its finished condition until the succeeding layer or pavement is placed. The base shall be properly drained at all times.

V. Approval of Materials.

Before use, samples of all materials shall be submitted for test, and no material shall be used until approved.

VI. Tests.

The contractor shall provide labor, material, and transportation for the tests and sampling. The engineer shall provide expert services and testing and sampling equipment.

Sampling. The engineer shall follow A.S.T.M. methods of sampling. *See "Data Book—Field."*

Laboratory Tests. The methods of test shall be the latest revision of the following:

Gravel from Pit	Test	Number of Tests
Los Angeles abrasion test (for coarse aggregate)	A.S.T.M. C-131	One from each sample submitted in advance.
Sieve analysis	A.S.T.M. C-136	One from each source and if there is any apparent change.
Liquid limit	A.S.T.M. D-423	
Plasticity index	A.S.T.M. D-424	
Moisture density relations	A.S.T.M. D-698 (Modified A.A.S.H.O. for runways)	As required to provide a control for moisture and density field tests.

Field Tests. *See "Data Book—Field."*

Moisture content of material during compaction Density of completed base	At least one of each for every 500 sq. yd. on each layer. Sufficient tests to insure thorough and uniform compaction.

Sieve analysis shall be performed daily on mixture. Additional sieve analysis shall be made if there is any apparent change in mixture.

VII. Basis of Payment.

Specify that the contractor be paid at unit or lump sum price called for in the contract.

Give work included and/or excluded under this price.

Give method of measurement.

If unit price, itemize price units.

If lump sum, itemize basis of payment for extra work, including the following item: price per cubic yard for additional base course complete in place.

DRY-BOUND MACADAM BASE COURSE

Can be constructed in colder weather, and receive pavement sooner, than water-bound macadam base. Requires bituminous surfacing. Preferred if stone having percentage of wear of 50 is available.

I. Scope of Work.

II. Description.

This work shall consist of constructing a base course, composed of crushed stone, crushed gravel, or crushed slag, on a prepared subgrade or sub-base in accordance with the plans.

III. Aggregates.

Coarse aggregate and screenings shall consist of crushed stone, crushed gravel, or crushed slag. It shall be of reasonably uniform quality throughout and shall be clean and free from an excess of dust and flat or elongated pieces. Coarse aggregate shall have a percentage of wear by the Los Angeles abrasion machine test of not more than 45. Slag shall weigh not less than 70 lb. per cu. ft. Aggregate gradation shall conform to the following:

REQUIREMENTS FOR GRADING OF AGGREGATES

Sieve Designation	Percentage by Weight Passing Square-Mesh Sieves	
	Coarse Aggregate	*Screenings*
3 in.	100	
$2\frac{1}{2}$ in.	90–100	
$1\frac{1}{2}$ in.	25–60	
$\frac{3}{4}$ in.	0–10	
$\frac{3}{8}$ in.		100
No. 4		85–100
No. 100		5–25

Quantities of Aggregates. Sufficient coarse aggregate and screenings shall be used to make a compact, dense mass of the required thickness as indicated on the plans.

IV. Construction Methods.

Preparation of Previously Constructed Subgrade or Sub-Base. All loose or foreign material shall be removed.

Any ruts or soft yielding places that appear on the subgrade or sub-base shall be corrected and rolled until firm.

Necessary subgrade or sub-base material shall be added to conform to proper grade and cross section.

Subgrade or sub-base shall be rolled to even, firm foundation.

Blanketing Subgrade or Sub-Base. From 50 to 75 lb. of screenings shall be uniformly spread per square yard. The screenings shall be moistened and rolled until firm and smooth. The roller shall weigh at least 10 tons.

Weather Limitations. Base course shall not be constructed during freezing weather or on a wet or frozen subgrade or sub-base.

Thickness of Layers. The base course shall be constructed in complete layers of not less than 3-in. or more than 4-in. compacted thickness. When it is necessary to construct the base in more than one layer to conform to the required finished thickness each layer shall be constructed as described below.

Spreading Coarse Aggregate. Sufficient coarse aggregate shall be uniformly spread to give the required thickness for one layer when compacted.

Any thin, flat, or oversized aggregate that appears on the surface shall be removed.

All patches or areas of fine or undersized aggregate shall be removed and replaced with suitable aggregate.

The thickness of each layer shall be tested by depth blocks.

Coarse aggregate shall not be spread more than 2,000 sq. yd. and never more than 500 linear feet in advance of rolling and application of screenings.

Rolling. Immediately after the spreading of the coarse aggregate, it shall be compacted to the full width by rolling with a 3-wheel power roller weighing at least 10 tons. The rolling shall begin with the outside rear wheel covering equal parts of shoulder and coarse aggregate, and the roller shall be run forward and backward until the shoulder and the aggregate are firmly bound together.

When shoulders and edges of the base course have been firmly rolled, the rolling shall progress gradually from the edges to the center, each preceding rear-wheel track being uniformly lapped by one-half the width of such track, and shall continue until the entire area of the course has been rolled by the rear wheels. Rolling shall be continued until the aggregate is well keyed and does not creep ahead of the roller and until the surface is firm, even, and true to line, grade, and crown. Places inaccessible to roller shall be compacted by mechanical *or* hand tamping.

Applying Screenings. Immediately after compaction of the coarse aggregate, sufficient clean, dry screenings shall be uniformly applied, 20 to 30 lb. per in. of depth, to fill all voids. Dry rolling shall be continued while screenings are being applied. The roller shall be equipped with a broom. Screenings shall be spread in thin layers at a uniform and slow rate to insure filling all voids. Hand brooms shall be used where necessary.

Spreading screenings, brooming, and rolling shall be continued until the voids are completely filled. No excess screenings shall remain on the surface. Surface shall be rolled until firm and thoroughly compacted. The spreading, rolling, and brooming of screenings shall be performed on sections not to exceed 2,000 sq. yd., and never more than 500 linear ft.

Tolerances. The surface shall be true to the established grade. The surface shall not vary more than $\frac{3}{8}$ in. in 10 ft. from the true profile and cross section. The thickness shall not be less than $\frac{1}{4}$ in. from that required for the layer being constructed.

Reconstructing Damaged Base Course. Should the subgrade or sub-base at any time become soft or churned up with the base-course material, the contractor shall, without additional compensation, remove the mixture from the affected portion, reshape and compact the subgrade or sub-base, and replace the removed section in accordance with the foregoing requirements.

Maintenance and Protection of Base Course. The surface of any layer shall be maintained in its finished condition until the succeeding layer or pavement is placed.

V. Approval of Materials.

Before use, samples of all materials shall be submitted for test, and no material shall be used until approved.

Manufacturer's Certificate. *Omit if laboratory tests are required.* Materials may be used if accompanied by manufacturer's certificate of compliance pending any tests which may be made by the engineer. Manufacturer's certificates shall include certificate of compliance covering quality and grading of aggregates.

VI. Tests.

Sampling. The engineer shall follow A.S.T.M. methods of sampling. *See "Data Book—Field."*

Laboratory Tests. The methods of test shall be the latest revision of the following:

Aggregate		Number of Tests
Los Angeles abrasion test	A.S.T.M. C-131	One from sample submitted in advance.
Sieve analysis	A.S.T.M. C-136	One for each size from each source, and
Weight of slag	A.S.T.M. C-29	if there is any apparent change.

Field Tests. Sieve analysis of aggregates shall be made daily. Additional sieve analysis shall be performed if there is any apparent change in aggregate gradation.

VII. Basis of Payment.

Specify that the contractor be paid at unit or lump sum price called for in the contract.

Give work included and/or excluded under this price.

Give method of measurement.

If unit price, itemize price units.

If lump sum, itemize basis of payment for extra work including the following item: price per square yard for base course complete in place.

WATER-BOUND MACADAM BASE COURSE

Can be used for low-type highway surface. Requires time to dry out before wearing course is placed and needs extra protection in cold weather.

Instructions for Specifying.

Use the same specification as for "Dry-bound Macadam Base Course" with the following changes:

In Article III, change percentage of wear of coarse aggregate from 45 to 50.

In Article IV, add the following to the paragraph "Weather Limitations": When the temperature is below 40° F., completed base course shall be protected against freezing, until it dries out, by a sufficient covering of straw or similar approved material.

After the paragraph "Applying Screenings," add the following:

Sprinkling. Immediately after the voids of a layer have been filled with screenings, the macadam shall be sprinkled, the sprinkler being followed by the roller. All excess screenings forming in piles or cakes on the surface shall be scattered by light sweeping. The sprinkling and rolling shall continue, and additional screenings shall be applied where necessary until all voids are completely filled and the coarse stone firmly set and bonded. The quantity of screenings and water shall be sufficient to completely fill and bond the entire depth of the coarse aggregate and to produce a granular surface.

Provision shall be made by the contractor for furnishing water at the site of the work by equipment of ample capacity and of such design as to assure uniform application.

ROAD MIX

MIXED-IN-PLACE GRAVEL MULCH

DENSE GRADED TYPE USING NEW GRAVEL

I. Scope of Work.

II. Description.

This work shall consist of preparing a road mix of new road gravel, mixed in place with bituminous material to a compacted thickness of $2\frac{1}{2}$ in., and placing it upon a prepared base course in accordance with the plans.

III. Prime Coat.

Base shall be cleaned of all dust and loose or foreign material with a power broom or power blower or both. Base must be dry, firm, even, and compact. If base is excessively dry, it shall be sprinkled lightly just before prime is applied. Atmospheric temperature must be above 50° F. Prime shall be applied uniformly with a pressure distributor, 0.2 to 0.6 gal. per sq. yd. (depending on surface texture) of medium-curing cut-back asphalt (MC-1) at a temperature between 80° F. and 125° F.; or rapid-curing cut-back asphalt (RC-1) at a temperature between 50° F. and 120° F.

MC shall conform to A.S.T.M. Spec. D-598.

RC shall conform to A.S.T.M. Spec. D-597.

Excess bituminous material shall be blotted up with sand.

Traffic shall be kept off, and at least 48 hr., preferably several days, shall be allowed for prime to set before aggregate is placed for the wearing course.

IV. Wearing Course.

Aggregate shall be selected pit-run gravel of hard, durable pebbles mixed with sand and clay. The gravel shall conform to the following gradation:

PERCENTAGE BY WEIGHT PASSING SIEVES (SQUARE OPENINGS)

Sieve Size	Per Cent Passing
$1\frac{1}{4}$ in.	100
$\frac{3}{4}$ in.	75–95
$\frac{1}{2}$ in.	65–85
No. 4	50–65
No. 10	35–50
No. 40	20–30
No. 100	10–18
No. 200	5–12

Medium-Curing Cut-Back Asphalt (MC-2) or (MC-3). First preference,

MC-2, temperature of application 150°–200° F., *or*
MC-3, temperature of application 175°–250° F.

Road Tar (RT). Alternative. Second Preference. *State credit or debit if used.* Road tar shall conform to A.S.T.M. Spec. D-490.

Specify:

		Placing Temperature, °F.	
Prime coat	RT-2	60–125	
	RT-3	80–150	
Wearing course	RT-4	80–150	Cold weather
	RT-5	80–150	Cold weather
	RT-6	80–150	
	RT-7	150–225	
Seal coat	RT-8	200–225	Cold weather
	RT-9	200–225	Cold weather
	RT-10	225–250	
	RT-11	225–250	

Temperature and Moisture Limitations. Apply bituminous material only when atmospheric temperature and that of the aggregate is 50° F. or above, and the aggregate does not contain more than 2% of moisture. If the aggregate is too dry to permit ready coating with the bituminous material, it shall be lightly sprinkled with water in advance of applying bituminous material.

Placing Aggregate and Bituminous Material. As soon as the prime coat has set, the gravel shall be spread uniformly to a loose depth sufficient to insure the required thickness after rolling. Aggregate may be spread mechanically or dumped from trucks and spread with a blade grader. Care shall be taken at all times not to disturb the primed base. MC-2 or MC-3 shall be applied in two approximately equal applications of 0.6 to 0.7 gal. per sq. yd. and shall total at least 1.25 gal. per sq. yd.

Partial Mixing. Disk or spring-tooth harrows, or rotary tillers, shall immediately follow the distributor after each application and shall pass up and down the treated strip until all free bituminous material has been incorporated with the aggregate.

Final Mixing. After the second application and partial mixing the treated aggregate shall be pushed into windrows with heavy-blade graders equipped with pneumatic tires on all wheels. Final mixing is then accomplished by rolling the windrows from side to side with the blade graders until the mixture is uniform in color and free from fat spots, clay balls, bitumen balls, and uncoated particles. From 12 to 15 complete turnovers of windrows are required. During mixing operations the blade graders shall mix the entire depth of the wearing course without injuring or disturbing the primed base. The equipment used for partial mixing may also be incorporated with the blade graders for final mixing.

Optional Placing and Mixing Methods. The gravel shall be placed on the primed surface in measured windrows of sufficient volume to produce the required thickness of pavement after final rolling. A travel plant or road-mix machine capable of producing a mixture of bituminous material and aggregate equal to that produced by the methods previously specified shall be used. If travel plant or road-mix machine is not equipped to measure and apply the bituminous material during the mixing operation, the total amount of bituminous material for the wearing course may be applied to the windrow.

The engineer shall have the right to order discontinuance of any equipment or method which fails to produce a satisfactory mixture.

Precautions. The engineer shall inspect the mixture. If it is too rich, aggregate shall be added; if too lean, bituminous material shall be added. Added material shall be remixed. If the mixture becomes wet before the mixing process is completed, blading shall be continued until the mixture has dried out.

The quantity and grade of bituminous material and the temperature of application, within specified limits, shall always be determined by the engineer, dependent upon the condition and character of the material to be treated and the weather conditions.

Spreading. When mixing is complete and the base is dry, the mixture shall be spread by blade graders to a uniform depth and shaped to required line, grade, and cross section.

Compaction by Rolling. Initial compaction shall be secured by rolling with wobble or straight-wheel rubber-tired rollers weighing not less than 4 tons. Final compaction shall be performed with 3-wheel or tandem power

rollers weighing from 5 to 8 tons. Rolling shall be in a longitudinal direction, starting at the edges and proceeding toward the center. Each trip of the roller shall overlap the previous trip by at least one-half the width of the roller.

Roller wheels shall overlap the shoulder sufficiently to compact the shoulder firmly against the pavement. Dragging or blading shall be done during rolling operations to keep the surface free from irregularities. Rolling shall be continued until all creases have been removed and 95% density attained.

Compaction by Traffic and Rolling. Alternative for Highways. *State credit or debit if used.* Edges and shoulders shall be rolled with 5- to 8-ton power rollers. The rest of the surface shall be compacted by traffic. During compaction the surface shall be dragged or bladed as necessary to fill ruts and to remove waves or other irregularities. If traffic does not produce 95% density, rolling with 5- to 8-ton power rollers shall be resumed.

Tolerances. The surface shall be true to the established grade. The thickness shall not be less than that shown on the plan. The surface shall not vary more than ¼ in. in 10 ft. from the true profile and cross section.

V. Seal Coat.

After the pavement has been opened to traffic from 10 to 30 days, the surface shall be swept thoroughly clean of all dust, dirt, caked clay, and loose or foreign material, and 0.3 gal. per sq. yd. of RC-2 shall be applied with a pressure distributor at a temperature between 100° and 175° F. Application shall be made only when the surface is dry and the atmospheric temperature is above 50° F.

While the material is still tacky, clean, dry, fine aggregate, approximately 10 to 20 lb. per sq. yd., shall be uniformly spread.

Fine Aggregate for Seal Coat shall consist of crushed stone, crushed slag, or screened gravel. Aggregate shall be of reasonably uniform quality throughout, clean and free from dust, and shall consist of hard, tough, durable fragments or pebbles. Crushed slag shall have a minimum weight of 70 lb. per cu. ft. Aggregate gradation shall conform to the following:

PERCENTAGE BY WEIGHT PASSING SIEVES (SQUARE OPENINGS)

Sieve Size	Per Cent Passing
½ in.	100
⅜ in.	90–100
No. 4	0–25
No. 10	0–10
No. 200	0–2

Brooming and Rolling. After fine aggregate has been spread, it shall be rolled immediately with 3-wheel or tandem power rollers weighing not less than 5 tons. Aggregate shall be broomed during rolling.

Fine aggregate shall be added if necessary to absorb bituminous material. Brooming and rolling shall be continued until the aggregate is thoroughly embedded and the surface is uniform in texture.

On airfield pavements all loose or surplus aggregate shall be swept off and removed.

VI. Approval of Materials.

Before use, samples of all materials shall be submitted for test, and no material shall be used until approved.

Manufacturer's Certificate. *Omit if laboratory tests are required.* Materials may be used if accompanied by manufacturer's certificate of compliance pending any tests which may be made by the engineer. Manufacturer's certificates shall include certificate of compliance covering quality and grading of aggregates and quality and grades of bituminous materials.

VII. Tests.

Specify that the contractor provide a laboratory building suitable as to size, light, heat, and water for the type of testing called for in the specification.

Sampling. The engineer shall follow A.S.T.M. methods of sampling. *See "Data Book—Field."*

Laboratory Tests. The methods of test shall be the latest revision of the following:

AGGREGATES		NUMBER OF TESTS
Sieve analysis	A.S.T.M. C-136	One from sample submitted in advance.
Weight of slag, stone, or concrete	A.S.T.M. C-29	One from each source.
BITUMINOUS MATERIAL		
MC	Conformance to A.S.T.M. D-598	One set of tests for each shipment.
RC	Conformance to A.S.T.M. D-597	
MIXTURE		
Percentage of bitumen	A.A.S.H.O. T-58	One test for every 5,000 sq. yd. Samples to be furnished by contractor.

Density. The contractor (*or owner*) shall cut at least one sample for each 5,000 sq. yd. of paving, which shall be tested for density.

Field Tests. Each load of bitumen shall be tested for temperature of application.

Sieve analysis and aggregate moisture-content tests shall be performed on at least one gravel sample for every 1,000 sq. yd. of wearing course.

Sieve analysis of fine aggregate for seal coat shall be made daily. Additional sieve analysis shall be made if there is any apparent change in aggregate gradation.

VIII. Basis of Payment.

Specify that the contractor be paid at unit or lump sum price called for in the contract.

Give work included and/or excluded under this price.

Give method of measurement.

If unit price, itemize price units.

If lump sum, itemize basis of payment for extra work including the following items: price per square yard for pavement complete in place including prime coat and seal coat; price per square yard for bituminous material in excess of specified amounts.

ROAD MIX

MIXED-IN-PLACE GRAVEL MULCH

DENSE GRADED TYPE USING EXISTING GRAVEL

Instructions for specifying: Use same specification as for "Road Mix, Mixed-in-Place Gravel Mulch, Dense Graded Type Using New Gravel" with the following changes:

Omit Article II and substitute the following:

II. Description.

This work shall consist of preparing the existing gravel surface and mixing the gravel with bituminous material to a compacted thickness of $2\frac{1}{2}$ in. in accordance with the plans.

Insert new Article III as follows:

III. Preparation of Existing Surface.

Surface shall be brought to required line, grade, and cross section with approved gravel.

Surface shall be scarified to a depth of 3 in. and to the width to be treated. All lumps of aggregate shall be thoroughly disintegrated. Oversize fragments shall be removed.

Sieve analysis shall be performed on existing gravel for conformity with specified gradation. If necessary new gravel or earth shall be added so that when thoroughly mixed with existing gravel the mixture will meet required gradation.

Sufficient loose aggregate shall be bladed into windrows to produce a finished wearing course of $2\frac{1}{2}$-in. compacted thickness.

The exposed base shall be thoroughly compacted by rolling with a 3-wheel or tandem power roller weighing not less than 10 tons. Any soft yielding spots that appear on the base shall be corrected and rolled until firm. The contractor shall carry on operations so that the entire base will receive a prime coat.

Article Numbering. Increase by one the number of all articles starting with Article III, "Prime Coat."

In Article IV: In paragraph "Aggregate," line 1, omit the words selected pit-run; *in paragraph "Placing Aggregate and Bituminous Material," omit the second sentence; in paragraph "Optional Placing and Mixing Method," omit the first sentence and substitute* The gravel shall be left in the windrows for mixing.

DOUBLE BITUMINOUS SURFACE TREATMENT

For Portland cement concrete base, use bituminous concrete or sheet asphalt.

I. Scope of Work.

II. Description.

This work shall consist of preparing the existing surface and constructing the bituminous surface treatment in accordance with the plans.

III. Preparation of Existing Surface.

Non-Bituminous Surface. Holes shall be patched with the same kind of material as the existing surface. Material shall be compacted to produce a surface conforming with the adjacent area. Humps or irregularities shall be removed by scarifying or blading and shall be rolled with a power roller weighing not less than 5 tons.

Bituminous Surface. Holes or depressions exceeding $\frac{3}{4}$ in. in depth shall be repaired by removing all loose or foreign material and filling with a bituminous concrete or sheet asphalt patching mixture. The patching material shall be compacted to produce a tight surface conforming with the adjacent area. A bituminous concrete or sheet asphalt leveling-course mixture shall be spread and compacted over areas designated by the engineer to be corrected for crown. *If leveling course is to be done by others omit it from this specification.*

Tolerances. The surface shall be true to the established grade and shall not vary more than $\frac{3}{8}$ in. in 10 ft. from the true profile and cross section.

IV. Prime Coat.

Use on non-bituminous surface.

Prepared base course or road surface shall be cleaned of all dust, dirt, caked clay, and loose or foreign material by sweeping with power brooms or blowers or both, supplemented by hand brooms. When base is dry or only slightly damp and atmospheric temperature is 50° F. or above, 0.2 to 0.6 gal. per sq. yd. (depending on surface texture) of medium-curing cut-back asphalt (MC-1) shall be applied uniformly with a pressure distributor at a temperature between 80° and 125° F., *or* rapid-curing cut-back asphalt (RC-1) at a temperature between 50° and 120° F.

MC shall conform to A.S.T.M. Spec. D-598.

RC shall conform to A.S.T.M. Spec. D-597.

Excess bituminous material shall be blotted up with sand. Traffic shall be kept off, and at least 48 hr. and preferably several days shall be allowed for prime to set. The contractor shall protect the surface against damage during this interval.

V. Materials.

Aggregate shall consist of crushed stone, crushed gravel, or crushed slag, of reasonably uniform quality throughout, clean and free from an excess of dust. It shall have a percentage of wear by the Los Angeles abrasion machine test of not more than 40. Slag shall weigh not less than 70 lb. per cu. ft. Not less than 70% of the fragments of

crushed gravel retained on the No. 4 sieve shall consist of broken angular pieces. The aggregate shall be of such nature that a thorough coating of bituminous material will not strip off upon contact with water. Aggregate gradation shall conform to Table I.

TABLE I

REQUIREMENTS FOR GRADING OF AGGREGATE

PERCENTAGE BY WEIGHT PASSING SQUARE-MESH SIEVES

Type	Coarse	Fine
Aggregate size	$\frac{3}{4}$ in.	$\frac{3}{8}$ in.
SIEVE DESIGNATION		
1 in.	100	
$\frac{3}{4}$ in.	90–100	
$\frac{1}{2}$ in.	......	100
$\frac{3}{8}$ in.	20–55	85–100
No. 4	0–10	15–50
No. 8	0–5	0–15
No. 16	......	0–5

Asphalt Cement (AC). First Preference. Asphalt cement 120 to 200 penetration shall conform to A.A.S.H.O. Spec. M-20 or M-22. Temperature of application shall be 275° to 350° F.

Road Tar (RT). Alternative. Second Preference. *State credit or debit if used.* Road tar shall conform to A.S.T.M. Spec. D-490.

Specify:

		Placing Temperature, °F.	
Prime coat	RT-2	60–125	
	RT-3	80–150	
Surface treatment	RT-8	150–225	Cold weather
	RT-9	150–225	Cold weather
	RT-10	175–250	
	RT-11	175–250	

Emulsified Asphalt (EA). Alternative. Third Preference. *State credit or debit if used.* Emulsified asphalt shall be quick setting, conforming to A.S.T.M. Spec. D-401. The temperature of application shall be 80° to 120° F. If road surface is dry, it shall be sprinkled with 0.15 to 0.35 gal. of water per sq. yd. before prime coat is applied, the lesser amount for dense bases and the greater amount for open bases. Cover aggregate in all cases shall be spread before the emulsion breaks completely (turns from brown to black).

VI. Quantities of Materials.

Quantities of material per square yard shall be within the maximum and minimum quantities specified in Table II. The exact amounts shall be determined by the engineer to meet field conditions.

TABLE II

SEQUENCE OF PLACING OPERATIONS AND AMOUNTS OF MATERIAL REQUIRED PER SQUARE YARD

Sequence of Operation	Asphalt or Tar: *Bitumen gallons per square yard*	Asphalt or Tar: *Coarse Aggregate pounds per square yard*	Asphalt or Tar: *Fine Aggregate pounds per square yard*	Emulsified Asphalt: *Bitumen gallons per square yard*	Emulsified Asphalt: *Coarse Aggregate pounds per square yard*	Emulsified Asphalt: *Fine Aggregate pounds per square yard*
First application	0.30–0.50			0.20–0.30		
First cover $\frac{5}{8}$ in. aggregate		30–45			25–40	
Second application	0.20–0.30			0.40–0.50		
Second cover $\frac{3}{8}$ in. aggregate			15–25			10–20
	Min. total 0.7			Min. total 0.70		

This table is based on a specific gravity of 2.65. Adjust for other specific gravities to maintain same volume.

VII. Construction Methods.

Weather Limitations. Bituminous surface treatment shall be applied only when the existing surface to be treated and the aggregates are dry or only slightly damp and the atmospheric temperature is above 50° F. (*Emulsified asphalt may be permitted by the engineer in damp weather.*)

Rollers shall be self-powered 3-wheel or tandem type weighing from 5 to 8 tons. Wheels shall be equipped with scraping and sprinkling devices and shall be kept properly moistened at all times without excess oil or water.

First Application of Bituminous Material. Immediately before bituminous material is applied, the previously prepared or primed surface shall be cleaned of all dust, dirt, caked clay, and loose or foreign material by sweeping with power brooms or blowers or both, supplemented by hand brooms. The engineer shall carefully inspect the surface to determine its fitness to receive treatment. Bituminous material shall be applied uniformly with a pressure distributor. Adjacent structures and trees shall be protected.

First Spreading of Aggregate. Immediately after the first application of bituminous material, clean, dry, coarse aggregate shall be spread uniformly in amounts within the limits specified in Table II for "First cover $\frac{5}{8}$-in. aggregate." Aggregate shall be ready for immediate use before any bituminous material is applied and shall be spread with aggregate-spreading equipment or by hand method. When hand spreading is employed, aggregate shall be spread by means of shovels from stockpiles adjacent to the areas to be treated, or from trucks operated backward. In no case shall aggregate be dumped directly on areas to be treated. Aggregate shall be spread ahead of truck or spreader wheels so that bituminous material will be covered before the wheels pass over it. The aggregate shall be placed in sufficient quantities, within the specified limitations, to provide a small roll of surplus material in front of the broom drag to prevent the broom drag from turning over the coated aggregate. Back spotting (or sprinkling) of additional aggregate over areas having insufficient cover shall be done by hand and shall be continued during the operations whenever necessary.

Rolling and Brooming. Rolling shall be started as soon as sufficient aggregate is spread to prevent pick-up of the bituminous material. Broom dragging shall start as soon as possible after rolling has started and after the surface has sufficiently set to prevent excessive marking. Further broom dragging shall be done as often as necessary to keep aggregate uniformly distributed over the surface. Broom dragging, rolling, and back spotting shall be continued until the surface is cured and the aggregate sufficiently keyed and set in the bituminous material. Places inaccessible to roller shall be compacted by hand tampers.

Any aggregate that becomes coated or mixed with dirt or any other foreign matter shall be removed and replaced with clean aggregate and rerolled. All surplus aggregate shall be swept off the surface and removed before the second application of bituminous material.

The contractor shall maintain and protect the treated areas by barricades, if necessary, until the second application of bituminous material, which shall follow not less than 24 hr. after the construction of the first course provided weather conditions permit. If the treated surface is excessively moistened by rain, it shall be allowed to dry for such time as it is deemed necessary by the engineer.

Second Application of Bituminous Material shall be made in the same manner as specified under "First Application of Bituminous Material."

Second Spreading of Aggregate. Immediately after the second application of bituminous material, clean, dry, fine aggregate shall be spread uniformly in amounts within the limits specified in Table II for "Second cover $\frac{3}{8}$-in. aggregate." The manner of spreading, brooming, and rolling shall conform to the methods set forth under "First Spreading of Aggregate" and "Rolling and Brooming." The finished surface shall be uniform, firm, and free from ruts and porous areas.

Tolerances. The finished surface shall be true to the established grade and shall not vary more than $\frac{3}{8}$ in. in 10 ft. from the true profile and cross section.

Maintenance and Protection of Pavement. During the construction of this treatment the surface shall be protected from all traffic other than that absolutely essential to its construction. The completed surface shall not be opened to traffic until after the bituminous material has hardened sufficiently, usually 48 hr. after the last application. The contractor shall spread, broom, and roll additional fine aggregate to absorb any excess bituminous material.

Approximately 10 days after completion of this treatment the contractor shall remove all loose aggregate.

VIII. Approval of Materials.

Before use, samples of all materials shall be submitted for test, and no material shall be used until approved.

Manufacturer's Certificate. *Omit if laboratory tests are required.* Materials may be used if accompanied by manufacturer's certificate of compliance pending any tests which may be made by the engineer. Manufacturer's certificates shall include certificate of compliance covering quality and grading of aggregates and quality and grades of bituminous materials.

IX. Tests.

Sampling. The engineer shall follow A.S.T.M. methods of sampling. *See "Data Book—Field."*

Laboratory Tests. Methods of test shall be the latest revision of the following:

Aggregate		Number of Tests
Los Angeles abrasion test	A.S.T.M. C-131	One from sample submitted in advance.
Sieve analysis	A.S.T.M. C-136	One for each size from each source, and if there is any apparent change.
Weight of slag	A.S.T.M. C-29	
Bituminous Material		
AC	Conformance to A.A.S.H.O. M-20 or M-22	One set of tests for each shipment.
RC	Conformance to A.S.T.M. D-597	
MC	Conformance to A.S.T.M. D-598	

Field Tests. Each load of bitumen shall be tested for temperature of application.

Sieve analysis of aggregates shall be performed daily. Additional sieve analysis shall be made if there is any apparent change in aggregate gradation.

X. Basis of Payment.

Specify that the contractor be paid at unit or lump sum price called for in the contract.

Give work included and/or excluded under this price.

Give method of measurement.

If unit price, itemize price units.

If lump sum, itemize basis of payment for extra work including the following items:

Price per square yard for double bituminous surface treatment complete in place including prime coat and preparation of existing surface.

Price per ton for bituminous concrete or sheet asphalt for leveling course complete in place.

PENETRATION MACADAM WEARING COURSE

I. Scope of Work.

II. Description.

This work shall consist of constructing a 3-in. compacted depth pavement of crushed stone or crushed slag, penetrated and sealed with bituminous material, on a prepared base in accordance with the plans.

III. Materials.

Aggregate shall consist of crushed stone or crushed slag. It shall be of reasonably uniform quality throughout and shall be clean and free from an excess of dust and flat or elongated pieces. Rock or slag shall have a percentage of wear by the Los Angeles abrasion machine test of not more than 40. Slag shall weigh not less than 70 lb. per cu. ft. Aggregate gradation shall conform to the following:

REQUIREMENTS FOR GRADING OF AGGREGATE

	Percentage by Weight Passing Square-Mesh Sieves		
Sieve Designation	Coarse Aggregate	Key Aggregate	Fine Aggregate
$2\frac{1}{2}$ in.	100		
2 in.	90–100		
$1\frac{1}{2}$ in.	35–70		
1 in.	0–15	100	
$\frac{3}{4}$ in.		90–100	
$\frac{1}{2}$ in.	0–5		100
$\frac{3}{8}$ in.		20–55	85–100
No. 4		0–10	15–50
No. 8		0–5	0–15
No. 16			0–5

Asphalt Cement (AC). First Preference. Asphalt cement shall conform to A.A.S.H.O. Spec. M-20 or M-22. *Specify within the following limits. For heavy or continuous traffic use the lower penetration.*

Location	Grade	Temperature of Application, °F.
Cold climate	(AC) penetration 120–150 or 150–200	275–350
Temperate climate	(AC) penetration 85–100 or 100–120	275–350
Tropical climate	(AC) penetration 85–100	275–350

Road Tar (RT). Alternative. Second Preference. *State credit or debit if used.* Road tar shall conform to A.S.T.M. Spec. D-490.

Specify as per climate:

Location	Grade	Temperature of Application, °F.
Cold climate	RT-10 or 11	175–250
Temperate climate	RT-11	175–250
Tropical climate	RT-11 or 12	175–250

The temperature of application for seal coat shall be 225°–250° F.

Emulsified Asphalt (EA). Alternative. Third Preference. *See Art. V. below.*

IV. Construction Methods.

Weather Limitations. Bituminous material shall be applied only when aggregate is dry and atmospheric temperature is above 45° F.

Equipment shall include adjustable aggregate-spreading equipment, pressure distributor, heating equipment for bituminous material, blade grader, push and drag brooms, and power rollers.

Rollers shall be self-powered 3-wheel type weighing not less than 10 tons and shall be equipped with sprinkling devices and adjustable wheel scrapers. One roller shall be kept in operation for 1 hr. on each 100 sq. yd. of completed pavement, at a speed of not more than 3 miles per hour.

Bituminous Material shall be applied uniformly with a pressure distributor. Hand methods may be used in locations inaccessible to distributor.

Preparation of Previously Constructed Base. All loose or foreign material shall be removed.

Any ruts or soft yielding places that appear on the base shall be corrected and rolled until firm.

Rolling shall be continued until foundation is firm.

Spreading and Rolling Coarse Aggregate. Sufficient coarse aggregate shall be uniformly spread to be 3 in. thick when compacted.

Any thin, flat, or oversized aggregate that appears on the surface shall be removed.

All patches or areas of fine or undersized aggregate shall be removed and replaced with suitable aggregate.

Rolling shall start at the edge and work toward the center. Where no curb exists, one-half the width of the outer roller wheel shall overlap the shoulder sufficient times to compact the shoulder firmly against the pavement. Each trip of the roller shall overlap the previous trip by at least one-half the width of a rear wheel. Rolling shall be continued until aggregate is well keyed, does not creep ahead of the roller, and the surface is firm, even, and true to line, grade, and crown.

Places inaccessible to the roller shall be compacted with mechanical *or* hand tamping.

Tolerances. The surface shall be true to the established grade. The thickness shall not be less than shown on the plan. The surface shall not vary more than $\frac{3}{8}$ in. in 10 ft. from true profile and cross section.

First Application of Bituminous Material. From 1.5 to 1.7 gal. per sq. yd. shall be applied.

Spreading Key Aggregate. Immediately after the application of bituminous material, sufficient clean, dry key aggregate shall be uniformly spread to fill all voids—approximately 25 to 40 lb. per sq. yd.

Key aggregate shall be broomed into voids and rolled.

Scattering key aggregate and brooming shall continue during rolling until the voids are completely filled. Material shall be rolled until the surface is firm and thoroughly compacted. No excess cover shall remain on the surface.

Second Application of Bituminous Material. From 0.6 to 0.7 gal. per sq. yd. shall be applied.

Spreading Fine Aggregate. Uniformly clean, dry, fine aggregate shall immediately be spread in sufficient quantity—approximately 15 to 30 lb. per sq. yd.—to cover the surface completely. Sufficient additional fine aggregate shall be spread, broomed, and rolled to absorb any excess bituminous material that shows through during rolling.

After this operation road shall be opened to traffic.

Seal. At the end of 30 to 60 days preferably, and never less than 5 days, the surface shall be swept clean of all loose or foreign material and 0.3 to 0.4 gal. per sq. yd. of bituminous material shall be applied.

Uniformly clean, dry, fine aggregate—approximately 15 to 30 lb. per sq. yd.—shall be spread immediately.

Aggregate shall be rolled until firmly embedded.

Additional fine aggregate shall be spread, broomed, and rolled to absorb any excess bituminous material that shows through during rolling.

Approximately 10 days after completion of seal coat all loose aggregate shall be removed.

Tolerances. The surface shall be true to established grade. The finished surface shall not vary more than $\frac{3}{8}$ in. in 10 ft. from the true profile and cross section.

V. Emulsified Asphalt (EA). Alternative. Third Preference.

State credit or debit if used.

This type of pavement shall conform to the previous specification except as follows:

Emulsified asphalt shall be quick-setting, conforming to A.S.T.M. Spec. D-401. The temperature of application shall be 80° to 120° F.

The voids in the coarse aggregate shall be filled with fine aggregate to within $\frac{1}{2}$ in. of the surface prior to penetrating.

Quantities of material per square yard and sequence of application shall be as follows:

Coarse aggregate	Sufficient to be 3 in. thick when compacted
Fine aggregate—fill voids	Approximately 20–30 lb.
First application EA	Approximately 0.9–1.1 gal.
Key aggregate	Approximately 25–40 lb.
Second application EA	Approximately 1.2–1.3 gal.
Fine aggregate	Approximately 10–20 lb.
Seal coat EA	Approximately 0.4–0.5 gal.
Fine aggregate	Approximately 10–15 lb.

VI. Approval of Materials.

Before use, samples of all materials shall be submitted for test, and no material shall be used until approved.

Manufacturer's Certificate. *Omit if laboratory tests are required.* Materials may be used if accompanied by manufacturer's certificate of compliance pending any tests which may be made by the engineer. Manufacturer's certificates shall include certificate of compliance covering quality and grading of aggregates and quality and grades of bituminous materials.

VII. Tests.

Sampling. The engineer shall follow A.S.T.M. methods of sampling. *See "Data Book—Field."*

Laboratory Tests. Methods of test shall be the latest revision of the following:

Aggregate		Number of Tests
Los Angeles abrasion test	A.S.T.M. C-131	One from sample submitted in advance.
Sieve analysis	A.S.T.M. C-136	
Weight of slag	A.S.T.M. C-29	One for each size from each source and if there is any apparent change.
Bituminous Material		
AC	Conformance with A.A.S.H.O. M-20 or M-22	One set of tests for each shipment.
RT	Conformance with A.S.T.M. D-490	
EA	Conformance with A.S.T.M. D-401	

Field Tests. Each load of bitumen shall be tested for temperature of application.

Sieve analysis of aggregates shall be performed daily. Additional sieve analysis shall be made if there is any apparent change in aggregate gradation.

VIII. Basis of Payment.

Specify that the contractor be paid at unit or lump sum price called for in the contract.

Give work included and/or excluded under this price.

Give method of measurement.

If unit price, itemize price units.

If lump sum, itemize basis of payment for extra work including the following item: price per square yard for pavement complete in place, exclusive of base course.

Specify that deductions will or *will not be allowed for area occupied by manhole covers and other structures.*

ONE-COURSE BITUMINOUS CONCRETE PAVEMENT

High Type

Instructions for Specifying

Specify a 2-in. wearing course or surface course with tack or prime coat consisting of the same materials mixed, placed, compacted, sealed, and tested in accordance with "Wearing Course or Surface Course" as specified under "Two-Course Bituminous Concrete Pavement."

The wearing course shall be laid upon a prepared base.

Recommended bases are as follows:

For Fine or Coarse Mix	For Sheet Asphalt
Dry-bound macadam	
Water-bound macadam	
Penetration macadam	Penetration macadam
Bituminous macadam	Bituminous macadam
Bituminous concrete	Bituminous concrete
Portland cement concrete	Portland cement concrete

Specify prime coat for dry-bound macadam base.

Specify tack coat for all other bases.

TWO-COURSE BITUMINOUS CONCRETE PAVEMENT

Highest Type, Suggested for Airports and Heavy-Duty Pavement

I. Scope of Work.

II. Description.

This work shall consist of constructing a plant-mix, hot-lay, two-course bituminous concrete pavement.

Binder course	$1\frac{1}{2}$-in. compacted thickness
Wearing course	$1\frac{1}{2}$-in. compacted thickness

The pavement shall be constructed on a prepared base course in accordance with the plans.

III. Prime Coat.

Specify except for bituminous or Portland cement base.

The prime coat shall be placed only on dry, clean base free from loose or foreign material when atmospheric temperature is above 50° F. From 0.2 to 0.6 gal. per sq. yd. (depending on surface texture) of medium-curing cut-back asphalt (MC-1) shall be applied with a pressure distributor at a temperature between 80° and 125° F., or rapid-curing cut-back asphalt (RC-1) at a temperature between 50° and 120° F.

MC shall conform to A.S.T.M. Spec. D-598.

RC shall conform to A.S.T.M. Spec. D-597.

IV. Tack Coat.

Specify for bituminous or Portland cement base and where trucking or other conditions have injured the bonding qualities of the binder course.

The tack coat shall be applied like the prime coat, 0.08 to 0.15 gal. per sq. yd. of RC-1 at a temperature between 50° and 120° F.

V. Binder Course.

Description. The binder course shall consist of coarse aggregate and sand, uniformly mixed with asphalt cement, and shall be laid upon the prepared base to a finished thickness of $1\frac{1}{2}$ in.

Coarse Aggregate shall consist of crushed stone of reasonably uniform quality throughout, clean and free from an excess of dust and from flat or elongated pieces.

Crushed Slag. Alternative. *State credit or debit if used.* Crushed slag shall be air-cooled blast-furnace slag and shall consist of hard, angular fragments reasonably uniform in density and quality, reasonably free from thin, elongated, or glassy pieces, dirt, and other objectionable matter. It shall have a minimum weight of 70 lb. per cu. ft. This alternative requires an increase of 1% of bituminous material over that specified.

Note. Crushed stone is preferred.

Crushed Gravel. Alternative. *State credit or debit if used.* Crushed gravel shall be of uniform quality; it shall be composed of clean, sound, tough, durable pebbles or fragments of rock free from clay balls, vegetable matter, and other deleterious substances, and from thin, elongated, soft, or disintegrated pieces. Gravel shall be washed if necessary to have clean surfaces free from coatings or foreign matter and shall have at least 70% of fractured particles.

Note. Not considered equal to crushed stone.

All coarse aggregates shall have a percentage of wear by the Los Angeles abrasion machine test of not more than 50 for base or binder courses and 40 for surface courses, as per A.S.T.M. Test C-131. The aggregates shall be of such nature that a thorough coating of the bituminous material will not strip off upon contact with water.

Fine Aggregates shall consist of clean, tough, rough-surfaced grains, free from clay, loam, and other foreign matter. As delivered to the mixer it shall be free from clayey lumps or loosely bonded aggregations, and the individual particles shall be free from adhering dust. All shall pass a No. 4 sieve and not more than 5% a No. 200 sieve.

Asphalt Cement (AC). First Preference. Asphalt cement shall conform to A.A.S.H.O. Spec. M-20 or M-22. *Specify within the following limits; for heavy or continuous traffic, use the lower penetration.*

		Highways	Airfields
Cold climate	(AC) penetration	70–100	120–150
Temperate climate	(AC) penetration	50–85	100–120
Tropical climate	(AC) penetration	50–60	85–100

Road Tar (RT). Alternative. Second Preference. *State credit or debit if used.* Road tar shall conform to A.S.T.M. Spec. D-490.

Specify as per climate.

	Climate		Mixing	Placing
	Cold or Temperate	Tropical	Temperature, °F.	Temperature, °F.
Prime coat	RT-2	RT-2	....	60–125
Tack coat	RT-3	RT-3	....	80–150
Binder course	RT-11	RT-12	175–250	150–225
Wearing course	RT-11	RT-12	175–250	150–225
Seal coat	RT-11	RT-12	....	225–250

Mixture shall conform to the following:

PERCENTAGE BY WEIGHT PASSING SIEVES (SQUARE OPENINGS)

Sieve Size	Per Cent Passing
$1\frac{1}{2}$ in.	100
1 in.	78–100
$\frac{1}{2}$ in.	53–70
No. 4	30–48
No. 10	20–37
No. 40	10–21
No. 80	6–15
No. 200	3–8
Bitumen %	4–6.5

The exact amount of bitumen shall be determined by sample mixes which must show grains completely coated. Samples shall not bleed when compacted. No change will be made in contract price due to variations in quantity of bitumen.

	Tolerances for Approved Mix
Aggregate passing sieve No. 4 or larger	5%
Aggregate passing sieve No. 10, 40, and 80	4%
Aggregate passing sieve No. 200	2%
Bitumen	0.5%
Temperature of mixing	25° F.

See also p. 3-78 in "Data Book—Design" for more flexible ranges to suit local conditions.

Mixing shall be done in a suitable pug mill or continuous mixer. Minimum time of mixing shall be 30 sec., and mixing shall be sufficient to coat all particles. The temperature of the materials when mixed shall be as follows:

Aggregates	150° to 325° F. and never more than 25° F. above temperature of bituminous material
Asphalt	225° to 350° F.

Transporting shall be done in trucks having insulated, tight, clean, oiled boxes. Each load shall be covered.

Placing shall be done only when surface is dry and atmospheric temperature is above 40° F. Placing shall not start until prime coat has set.

The contact surfaces of all structures shall be painted with hot bituminous material as used in the mixture.

The mixture shall be spread by mechanical spreaders; only in inaccessible locations shall the mixture be spread by hand. Hand placing shall be from a steel dump board by means of hot shovels. Hand spreading shall be with hot rakes of suitable design. The temperature of the mixture when spread shall be between 225° and 350° F.

Compacting. The mixture, as soon after it is spread as it will bear the roller without undue displacement or hair cracking, shall be rolled with a 3-wheel roller weighing not less than 10 tons. Roller wheels shall be equipped with scraping and sprinkling devices and shall be kept properly moistened without excess of oil or water. Rolling shall start longitudinally at the sides and proceed toward the center. Each trip of the roller shall overlap the previous trip by at least 1 ft. Alternate trips of the roller shall be of slightly different lengths. The speed of the roller shall not exceed 3 miles per hour.

Where no curb exists the roller wheel shall overlap the shoulder a sufficient number of times to compact the shoulder firmly against the pavement. Then rolling shall be done diagonally in two directions with a tandem roller weighing not less than 8 tons, the second diagonal rolling crossing the lines of the first. If pavement width permits, rolling shall also be at right angles to the center line. Rolling shall be continued until all creases have been removed and 95% density attained. Mechanical tampers shall be used for compacting in locations inaccessible to the roller.

Joints. When new mixture is placed against previously placed mixture, the joint shall be cut back to a clean, vertical surface and painted with hot bituminous material as used in the mixture.

Tolerances. The surface shall be true to the established grade. The thickness shall not vary more than $\frac{1}{4}$ in. from that shown on the plan. The finished surface shall not vary more than $\frac{1}{4}$ in. in 10 ft. from the true profile and cross section.

VI. Wearing Course or Surface Course.

The wearing course shall consist of the same materials plus mineral aggregate and shall be mixed, placed, and compacted the same as the binder course, except as follows:

Mineral Filler shall consist of thoroughly dry stone dust, Portland cement, or other artificially or naturally powdered mineral dust, 65% to 100% of which will pass a No. 200 mesh sieve.

Fine Aggregate. Ninety-eight to 100% shall pass a No. 10 sieve and not more than 5% a No. 200 sieve.

Mixture. Mixture of aggregates, mineral filler, and bitumen shall conform to the following:

Note. Specify sheet asphalt or fine or coarse mix.

Sheet Asphalt for City Streets. *Specify within the following limits. For heavy or continuous hot-weather traffic use the lower penetration.*

		Highways and Airports
Cold climate	(AC) penetration	60–85
Temperate climate	(AC) penetration	60–70
Tropical climate	(AC) penetration	50–60

MIXTURE

Passing	Retained on	Per Cent
No. 10 sieve	....	100
No. 10 sieve	No. 40 sieve	10–40
No. 40 sieve	No. 80 sieve	20–45
No. 80 sieve	No. 200 sieve	12–32
No. 200 sieve	....	10–20
Bitumen %		9.5–12

Fine and coarse mix is usually cheaper and has better traction, and stability is more easily controlled than with sheet asphalt.

	Fine Mix For Streets and Airport Runways	Coarse Mix For Highways
Percentage by Weight Passing Sieves (Square Openings)		
Sieve Size	*Per Cent Passing*	*Per Cent Passing*
1 in.		100
$\frac{3}{4}$ in.		85–100
$\frac{1}{2}$ in.	100	73–88
$\frac{3}{8}$ in.	84–100	
No. 4	60–73	46–60
No. 10	43–57	32–47
No. 40	23–33	16–26
No. 80	13–20	10–18
No. 200	4–8	4–8
Bitumen %	5–7.5	5–7

The exact amount of bitumen shall be determined as specified for the binder course.

Joints shall be at least 1 ft. from joints in the binder course and shall present the same texture, density, and smoothness as the rest of the pavement.

Outside Edges. The outside edges of the pavement shall be trimmed neatly to line while the course is being finished.

Tolerances. The finished surface shall not vary more than $\frac{1}{8}$ in. in 10 ft. from the true profile and cross section.

Appearance. The finished surface shall be uniform in texture and appearance.

Protection of Pavements. After final rolling, no vehicular traffic of any kind shall be permitted on the pavement until it has cooled and hardened and in no case in less than 6 hr.

VII. Seal Coat.

Use only with coarse mix. Specify for airport runways and where impervious highway surface is desired.

After pavement has been completed and preferably after being open to traffic for at least 30 days, from 0.15 to 0.25 gal. per sq. yd. of RC-2 shall be applied with a pressure distributor at 100° to 175° F. The seal coat shall be applied when the surface is dry, clean, and free from all loose or foreign material and atmospheric temperature is above 50° F. It shall be covered immediately with 15 to 25 lb. of $\frac{3}{8}$-in. chips for highways and/or 10 to 20 lb. of thoroughly air-dry sand for airport pavements. It shall be rolled immediately with a 5- to 6-ton tandem roller. Aggregate shall be broomed while rolling. Brooming and rolling shall be continued until the aggregate is thoroughly embedded. On airport pavements all loose or surplus aggregate shall be swept off and removed.

VIII. Approval of Materials.

Before use, samples of all materials shall be submitted for test, and no material shall be used until approved.

Manufacturer's Certificate. *Omit if laboratory tests are required.* Materials may be used if accompanied by manufacturer's certificate of compliance pending any tests which may be made by the engineer. The manufac-

turer's certificates shall include certificate of compliance covering quality and grading of aggregates and quality and grades of bituminous materials.

IX. Tests.

Specify that the contractor provide a laboratory building suitable as to size, light, heat, and water for the type of testing called for in the specification.

Sampling. The engineer shall follow A.S.T.M. methods of sampling. *See "Data Book—Field."*

Laboratory or Plant Tests. The methods of test shall be the latest revision of the following:

		Number of Tests
Coarse Aggregate		
Los Angeles abrasion test	A.S.T.M. C-131	One from sample submitted in advance.
Sieve analysis	A.S.T.M. C-136	
Per cent of clay lumps	A.S.T.M. C-142	
Fine Aggregate		
Sieve analysis	A.S.T.M. C-136	One from each source and if there is any apparent change.
Mineral Filler		
Sieve analysis	A.S.T.M. D-546	Daily sieve analysis.
Bituminous Material		
AC	Conformance to A.A.S.H.O. M-20 or M-22	One set of tests for each shipment.
RC	Conformance to A.S.T.M. D-597	
MC	Conformance to A.S.T.M. D-598	
Mixture		
Percentage of bitumen	A.A.S.H.O. T-58	Daily test.
Mechanical analysis	A.A.S.H.O. T-30	Daily test.

Density. The contractor shall cut at least one sample of paving and one additional sample for each 5,000 sq. yd., which shall be tested for density.

Field Tests. Each load of bitumen or mixture shall be tested for temperature of application.

X. Inspection of Paving Plant.

Inspection of paving plant shall be in accordance with the latest revision of A.S.T.M. D-290.

XI. Basis of Payment.

Specify that the contractor be paid at unit or lump sum price called for in the contract.

Give work included and/or excluded under this price.

Give method of measurement.

If unit price, itemize price units.

If lump sum, itemize basis of payment for extra work including the following items:

Price per square yard for 1½-in. binder course complete in place.

Price per square yard for 1½-in. wearing course complete in place.

Price per square yard for prime coat.

Price per square yard for tack coat.

Price per square yard for seal coat.

Price per ton for bituminous concrete complete in place.

Price per ton for sheet asphalt complete in place.

Specify deductions will or *will not be allowed for areas occupied by manhole covers and other structures.*

PORTLAND CEMENT CONCRETE PAVEMENT

(BRIEF SPECIFICATION)

I. Scope of Work.

Work Included. This work shall include construction of a concrete pavement on a prepared sub-base in accordance with the plans. *Include and specify gutters, catch basins, and drainage under this or other heading.*

Work Not Included.

II. Materials.

Cement shall be Portland and shall conform to the A.S.T.M. requirements C-150-40T, I or II, and shall be tested by a laboratory selected by the engineer at the cost of the contractor.

Sand shall consist of clean, sound, durable grains free from dirt, dust, clay, or harmful substances.

Sand shall be uniformly graded from 100% passing No. 4 sieve to not more than 10% passing No. 100 sieve. Samples shall be submitted for the approval of the engineer and for testing. Sand shall not show darker than a very light amber when tested by the colorimetric method.

Stone or Gravel. Aggregate shall be of hard crystalline rock or gravel free from shale or decomposed pieces. It shall be uncoated and clean. Samples shall be submitted to the engineer for approval. The gradation shall be uniform and between the limits of 2 in. and $\frac{1}{4}$ in. in size.

Water shall be clean and free from oil and salt or injurious substances.

Expansion Joint Filler shall be preformed bituminous fiber.

Joint Sealer shall be road tar, RT-12, or asphalt cement, penetration 80 to 150.

Reinforcing Steel shall be new billet stock of intermediate grade, in accordance with the latest A.S.T.M. Spec. A-15. The contractor shall furnish the engineer a certificate from the manufacturer stating that the product is open-hearth steel and giving those chemical and physical properties of the heat required by the latest A.S.T.M. specification.

III. Concrete.

Concrete shall be so proportioned as to give a strength of 4,000 lb. per sq. in. at 28 days. The total water content shall not exceed 5 gal. per sack of cement. Slump shall be between $1\frac{1}{2}$ in. and 3 in. Aggregates shall be batched by weight. Cement shall be measured by sacks or by weight, and water shall be accurately measured by volume or weight.

Four cylinders for each 150 cu. yd. of concrete shall be taken in accordance with A.S.T.M. Spec. D-31, two of which shall be broken at 7 days and two at 28 days. The taking and breaking of the cylinders shall be at the contractor's expense and performed by a testing laboratory approved by the engineer.

IV. Subgrade.

The subgrade shall be graded and rolled with a roller of not less than 8 tons; it shall be tested with a scratch board resting on the forms, and high or low places shall be corrected.

The subgrade shall be moistened before concrete is placed.

V. Forms.

Forms shall be of steel or of wood 3 in. thick dressed on the top and inside. Built up, battered, bent, twisted, broken, or dirty forms shall not be used. Forms shall be cleaned and oiled before use and shall be securely staked and braced and have rigid, tight connections at joints.

VI. Mixing Concrete.

Concrete shall be mixed in a batch mixer of standard type with a drum speed of 200 to 225 peripheral feet per minute. Mixing time shall be 1 min. for batches of 1 cu. yd. or under and shall be increased 15 sec. for each additional $\frac{1}{2}$ yd. or fraction.

Retempering concrete will not be allowed. Air-slaked or lumpy cement shall not be used. The contents of the mixer shall be completely discharged before each new batch is loaded.

Transit-Mix Concrete may be used, provided that it conforms to the specifications and tests herein described, and further provided that the central plant producing the concrete and equipment and the transporting of it are, in the opinion of the engineer, suitable for the production and transportation of the specified concrete

VII. Placing of Concrete.

Concrete shall not be placed until the subgrade is prepared and forms are set. Concrete shall be deposited with minimum rehandling and in one layer. Spading or vibrating shall be done adjacent to forms and joints. Placing shall be continuous without bulkheads.

VIII. Finishing and Curing.

Strike-Off. The concrete shall be struck off and tamped by a mechanical or hand screed.

Longitudinal Floating shall be done with a float at least 10 in. wide by 12 ft. long.

Scraping. Excess laitance or water shall be removed by scraping with a 10-ft. straightedge.

Straightedge Check shall be made while concrete is plastic with a 10-ft. straightedge placed at 5-ft. intervals and overlapping 5 ft. on each check.

Belting shall be done transversely with a canvas or rubber belt. A burlap drag may be used instead of belting.

Transverse Brooming (*omit for airports*) shall be done before initial set by lightly drawing a steel or barn broom across the surface.

Joints and Edges shall be tooled and rounded.

Form Removal shall be carefully done without damage to green concrete and not before 12 hr. after placing of concrete. Holes, voids, or honeycomb shall be filled with 1 : 2 mortar and floated smooth. Expansion joints shall be cut free of concrete. Edges shall be protected by earth or planking.

Curing shall be by an approved moist curing method or by spraying with an approved curing compound.

Sealing Joints. Joints shall be cleaned and sealed with bituminous filler.

Opening to Vehicles will not be permitted for at least 7 days after placing of concrete.

Final Inspection. The pavement shall be clean and free from fractures, spalling, or defects. The surface shall show no depression more than $\frac{1}{4}$ in. under a 10-ft. straightedge.

IX. Special Conditions.

Admixtures such as vinsol resin, calcium chloride, anti-freeze, etc., shall be used only with the approval of the engineer.

X. Frost Protection.

Concreting shall not be continued when the air temperature is below 45° F. unless the aggregates and/or water are heated to produce a placing temperature of the concrete between 60° F. and 90° F. and unless adequate provisions are made for maintaining protection against freezing of the concrete for at least 7 days after placing. No concrete shall be placed on frozen sub-grade.

XI. Tests.

In addition to the cylinder tests mentioned under "Concrete," if evidence of faulty workmanship exists, violation of specification, or likelihood of concrete having been frozen, tests may be required, which shall be made at the contractor's expense under the direction of the engineer.

PORTLAND CEMENT CONCRETE PAVEMENT

(FULL SPECIFICATION)

I. Scope of Work.

II. Description.

This work shall consist of constructing a concrete pavement on a prepared subgrade in accordance with the plans and specifications.

III. Materials.

Portland Cement shall conform to A.S.T.M. C-150, Type II, *or to A.S.T.M. C-175, Type IIa, if vinsol resin is used.* *See "Air-Entraining Cement," p. 128.* Cement shall be tested at the contractor's expense at the mill by a testing laboratory approved by the engineer and shall be delivered to the job or batching plant in sealed cars. Manufacturer's test sheet and guaranty certificate shall be delivered to the engineer before seals on any car are broken.

Water shall be clean and free from oil, acids, salts, and injurious substances.

Coarse Aggregate shall consist of clean washed gravel or crushed stone, free from any adherent coating and vegetable matter. The amount of deleterious substances shall not exceed the following limits when tested in accordance with A.S.T.M. Spec. C-33.

	Per Cent
Soft fragments	2.00
Coal and lignite	0.25
Clay lumps	0.25
Material less than No. 200 sieve	0.5
Crusher dust less than No. 200 sieve	0.75

Loss of weight after 5 cycles of the sodium sulfate soundness test, A.S.T.M. C-88, shall not be more than 10%. The gradation of the aggregate shall be within the following limits:

Laboratory Sieves—Square Openings	Per Cent by Weight Passing
2 in.	95–100
1 in.	35–70
No. 4	0–6

The contractor shall store and batch aggregate in two sizes: 2 in. to 1 in. and 1 in. to No. 4.

Fine Aggregate shall be clean, rough-surfaced sand capable of developing 100% of the tensile strength of standard Ottawa sand at 7 and 28 days. Sand shall not contain more than 1% clay lumps or 0.25% coal and lignite when tested in accordance with A.S.T.M. Spec. C-33. Sand shall show not darker than a very light amber when

tested by the colorimetric method. Loss of weight after 5 cycles of the sodium sulfate soundness test, A.S.T.M. C-88, shall not be more than 10%. The gradation shall be within the following limits:

Laboratory Sieves—Square Openings	Per Cent by Weight Passing
No. 4	95–100
No. 16	45–70
No. 50	15–30
No. 100	3–8
No. 200	0–3

Fine aggregate shall not have a variation in fineness modulus greater than plus or minus 0.20 from that of the approved sample.

Curing Agents shall be wet earth, straw, burlap or cotton mats, or curing liquids. The curing method shall retain after 72 hr. at least 90% of the original water in the mix when tested by A.S.T.M. Spec. C-156.

Mooring Eyes shall be of galvanized wrought-iron bars conforming to Fed. Spec. QQ-I-686 of size and shape shown on the plans.

Reinforcing Steel. New billet stock of structural or intermediate grade conforming to the following:

A.S.T.M.	Type
A-15	Bars and rods
A-185	Steel wire fabric

Tie bars which are to be bent after one end is encased in concrete shall be structural grade.

Expansion Joint Material shall conform to the latest revision of the A.S.T.M. or A.A.S.H.O. specification for preformed non-extruding filler.

Specify one or more of the following:

Specification	Type
A.S.T.M. D-544	Cork, sponge rubber, or cork rubber
A.A.S.H.O. M-59	Fiber bituminous
A.A.S.H.O. M-90	Redwood board

Joint Sealing Material shall be an asphalt filler conforming to the latest revision of A.A.S.H.O. Spec. M-18 type A, or an approved mastic filler.

IV. Storage of Materials.

Insert from specifications for "Structural Concrete."

V. Control of Concrete.

The contractor shall furnish concrete which will conform with the following requirements. *The engineer may specify lower required strength in localities where aggregates and conditions necessitate.*

28-Day Flexural Strength	28-Day Compressive Strength	Sacks Cement per Cubic Yard	Slump, Standard	Slump, Vibratory	W/C Ratio	Sand Aggregate Ratio
pounds per square inch			*inches*		*gallons per sack, maximum*	*per cent*
700	4,500	Not less than 6	$1\frac{1}{2}$ to 3	1 to $1\frac{1}{2}$	$5\frac{1}{2}$ cold climates, 6 mild climates	30 to 40

The contractor shall submit the mix that he intends to use, based on proportional weights of cement, saturated surface dry aggregates, and water. This mix must be proved by preliminary tests at least 30 days in advance of concreting operations and show a strength at 28 days of 15% higher than the ultimate strength required.

Job Mix Adjustment. Water content shall not be increased from the amount required for the design mix unless cement at the required W/C ratio is added.

The engineer may increase the cement or decrease the aggregates without extra cost to the owners in case the mix adopted does not produce the required strength, plasticity, or yield.

The engineer may vary the relative weights of fine and coarse aggregates to improve the workability or consistency.

VI. Batching of Concrete.

Insert from specifications for "Structural Concrete."

VII. Transporting Materials.

Insert from specifications for "Structural Concrete."

VIII. Subgrade.

The subgrade shall be graded and rolled to the exact cross section and elevations and shall be tested with an approved template before concreting. High areas shall be reduced to grade and low areas raised to grade with approved material compacted in place, as directed.

The subgrade shall be moistened in advance of concreting but shall not be muddy or excessively wet.

At all times there shall be at least 500 linear feet of prepared and approved subgrade in advance of placing concrete.

IX. Forms.

Forms shall have a height equal to the slab thickness. Built-up, battered, bent, twisted, or broken forms shall be removed from the work. All forms shall be cleaned and oiled each time they are used.

Forms shall be so constructed and set as to resist without springing or settlement the pressure of the concrete and the operation of the finishing machines.

The subgrade under the forms shall be rolled before forms are set and shall be tamped thoroughly after forms are in place.

Steel Forms shall be at least 10 ft. long for tangents and 5 ft. long for curves and shall have a base width of at least 8 in. Steel forms shall be made of metal not less than $\frac{3}{16}$ in. thick. The forms shall be true to a straight line with a tolerance of $\frac{1}{8}$ in. in 10 ft. for the top surface and $\frac{1}{4}$ in. in 10 ft. for the upstanding leg.

Forms shall have square ends connected with a rigid lock joint.

Flexible or wood forms shall be used for curves of less than 150-ft. radius.

Wooden Forms. When permitted to be used by the engineer, wooden forms shall be 3 in. thick and dressed on three sides. Wood forms shall be securely staked and braced.

X. Reinforcement and Joint Assemblies.

Supports. Reinforcing steel shall be held in place by approved steel chairs or devices, except for layer placing of single mats. Rocks, broken bricks, wood blocks, or concrete fragments will not be allowed.

Bar or Rod Mats shall be constructed and placed according to plan dimensions. Intersections shall be firmly clipped or welded. Bar or rod laps shall be at least 40 diameters.

Steel Wire Fabric shall be placed according to plan dimensions. Adjoining sheets shall have 12-in. laps held in place by wires or clips spaced not more than 4 ft. apart.

Dowels, Tie Bars, and Joint Assemblies shall be constructed and installed according to plan and accurately held in place by approved rigid devices. No steel reinforcement shall be placed within 2 in. of an exposed surface.

XI. Mixing and Placing Concrete.

Equipment and Personnel. Concreting operations shall not commence until all necessary equipment and sufficient competent personnel for all operations are on hand and approved by the engineer.

Paving Mixer shall be a boom and bucket delivery type. The mixer drum shall not be charged in excess of 110% of manufacturer's rated capacity. The mixer shall be equipped with a timing device with provision to lock the discharge lever during full time of mixing and provided with a bell adjusted to ring each time the lock is released. Water-measuring devices shall be accurate within 1%.

Time. The minimum mixing time, after all materials are in the drum, shall be 1 min. The mixer drum shall operate at a speed of 14 to 20 r.p.m.

Placing Concrete shall not commence or continue at any time unless forms are set and subgrade prepared for a distance of not less than 500 linear feet in advance of concreting.

Concrete shall be placed in its final position with minimum rehandling. Unreinforced concrete shall be deposited in one layer of such depth that after consolidation and finishing the required slab thickness and surface grade will be obtained.

Concrete adjacent to forms and joints shall be thoroughly spaded or vibrated. Internal vibrators shall operate at not less than 3,200 pulsations per minute. Over-vibration or manipulation causing segregation will not be permitted.

The paving mixer shall be operated, whenever practicable, outside the lane being placed. Concrete shall be placed continuous between joints without bulkheads.

Hand spreading shall be done only with shovels. Workmen shali avoid walking in freshly mixed concrete or on reinforcement assemblies.

Concrete shall be in place 7 days before adjacent lanes are placed.

Construction joint assemblies shall be on hand at all times and shall be installed when stoppage of more than 30 min. occurs in placing concrete and at the end of each day's work, when such stopping point does not occur at a regular expansion joint. No joint so formed shall be less than 15 ft. from any other joint.

Placing at Joints. Concrete shall be shoveled against both sides of expansion joint assemblies simultaneously. The concrete shall not be dumped from the mixer directly upon the joint assemblies.

Placing Reinforced Concrete shall be accomplished in two layers when approved chairs or supports are not used. The time allowed between the placing of the first and second layer shall not exceed 15 min. The first layer of concrete shall be placed and consolidated to the elevation of the reinforcement. The reinforcing units shall then be installed and the top layer of concrete deposited. The final position of the reinforcement shall be in accordance with plan dimensions.

XII. Finishing and Curing.

Concrete shall not be placed in excess of the amount which can be completely finished during daylight hours, unless satisfactory night lighting is provided. The finishing operations shall be completed with a minimum amount of manipulation.

Mechanical Finishing. The concrete shall be struck off and consolidated by a self-propelled spreading and finishing machine equipped with a screed to consolidate the concrete by pressure. At least 3 in. of concrete shall be carried in front of the strike-off screed. The number of passes shall be not more than 2.

Hand Finishing will be permitted in case of breakdowns or for small or odd-shaped areas. The strike-off template shall be at least 10 in. wide, made of steel weighing 20 lb. per ft., or of steel-shod 4-in. lumber. The screed shall be manipulated with a combined crosswise and forward motion with both ends resting on the side forms. After strike-off the concrete shall be tamped with a similar template.

Longitudinal Floating. The surface shall be floated with a 12-ft. to 16-ft. float. Each floated section shall overlap the previously floated section by 5 ft.

Scraping. The surface shall be scraped with a wood or metal straightedge 10 ft. long, operated so that all excess water and laitance are drawn from the surface.

Straightedging shall be done with a 10-ft. straightedge placed parallel to the center line at not more than 5-ft. intervals. Irregularities exceeding $\frac{1}{8}$ in. shall be corrected. Areas so disturbed shall be floated with a 3 ft. by 6 in. wooden float.

Belting. The surface shall be belted, after disappearance of water sheen, with a canvas, rubber, or burlap belt.

Burlap Drag. After belting, a wet burlap drag shall be laid on the surface and dragged forward.

Transverse Brooming (*omit for airports*) shall be done before initial set by lightly drawing a steel or barn broom across the pavement surface.

Joints and Edges shall be rounded to a radius of $\frac{1}{4}$ in. or $\frac{1}{2}$ in. and tooled for a width of 2 in. This work shall be done from a bridge which is not in contact with the concrete at any point.

Removal of Forms shall be carefully done without damage to the concrete. Prying against green concrete with crowbars, picks, and such tools shall not be permitted. Tie bars shall be carefully straightened with a pipe lever.

Forms shall not be removed less than 12 hr. after concrete is placed.

Holes, voids, or honeycomb on sides or edges of slabs shall be wetted and filled with 1 : 2 mortar floated smooth.

Any concrete spanning expansion joints shall be carefully cut away.

Curing shall consist of an initial covering for 24 hr. with wet burlap applied as soon as concrete has hardened, followed by a 7-day final curing period of ponding, spraying, or covering with wet earth, straw, or burlap or cotton mats kept saturated for 7 days. Instead of the wet curing an approved impervious membrane may be applied immediately after finishing.

Materials and methods for curing shall retain, after 72 hr., at least 90% of the original water in the mix, when tested by A.S.T.M. C-156.

Cleaning and Sealing Joints. The pavement shall be swept clean, and, after removal of all foreign material from the joints, joints shall be filled flush with specified joint filler. The joint filler shall not spill over the joint onto the adjacent surface. Joints shall be refilled where necessary before final acceptance.

XIII. Opening to Traffic.

Opening to traffic including the contractor's vehicles will not be permitted until the flexural strength of the concrete, as indicated by the modulus of rupture of beams tested in conformity with A.S.T.M. Designation C-78, is at least 550 lb. per sq. in.

If permanent shoulders are not in place a temporary earth shoulder shall be placed against the outside pavement edges before traffic is allowed on the pavement.

Opening to traffic shall not constitute a final acceptance of the pavement.

XIV. Final Inspection, Acceptance, and Tolerances.

Smoothness shall be tested by the engineer by means of surface-testing machine or straightedge applied to each separate lane of pavement. All surface variations of $\frac{1}{8}$ in. or more in 10 ft. must be ground off. Bush-hammering shall not be permitted.

Sections of pavement containing depressions with a depth in excess of $\frac{1}{4}$ in. in 10 ft. shall be removed and replaced at the contractor's expense. Such removed sections shall not be less than full lane width and full distance between joints in length.

Defects. Slabs containing excessive cracking, fractures, spalling, or other defects shall be removed and replaced as above, when directed by the engineer.

Pavement Thickness will be determined by at least 2 cores taken from each 1,000 linear feet of each lane and at such other locations as the engineer may direct.

Payment will not be made for slabs deficient in thickness by more than $\frac{1}{2}$ in. Such slabs shall be removed and replaced with concrete of required thickness at the expense of the contractor. Deductions for deficiency in thickness are herewith tabulated:

Deficiency in Thickness	Proportional Part of Contract Price Allowed
0.00 in. to 0.25 in.	100%
0.26 in. to 0.50 in.	Ratio $\frac{(\text{Actual thickness})^2}{(\text{Specified thickness})^2}$
Greater than 0.50 in.	None

Note. Include Sections XV, XVI, and XVII in the specifications for those projects or areas to which they are applicable, as noted.

XV. Air-Entraining Cements.

Air-entraining cements have been used in cold climates where the prevention of scaling due to salts in ice removal and to severe frost action is important. Natural cement has also been used for this purpose.

Air-Entraining Cement shall conform to the latest revision of A.S.T.M. C-175.

Strength and Unit Weight. *The strength requirements of Section IV, "Control of Concrete," shall be modified to:* Required 28-day flexural strength shall be 600 lb. per sq. in. and required 28-day compressive strength shall be 4,000 lb. per sq. in.

The engineer shall adjust the mix so that the same cement factor required for use with normal Portland cement shall be obtained. This shall be done by decreasing the amount of fine aggregate and water to offset the bulking action caused by air entrainment. The total air determined by weighing air-entrained concrete and comparing with air-free concrete shall not be less than 3% or more than 6% as per A.S.T.M. C–138.

Concrete Made with Air-Entraining Cements may be batched and hauled to the site in transit-mix trucks. At the site of placing, the transit-mix truck shall be brought to a complete stop, and the concrete shall be mixed not less than 50 revolutions or more than 150 revolutions at the manufacturer's specified speed. The drum shall be vented during mixing. Excessive air entrainment due to over-long mixing shall be corrected as directed by the engineer.

Natural Cement shall conform to A.S.T.M. C-10 with beef tallow interground at an amount of 0.05% to 1%. It shall be included in the mixture at the rate of one 80-lb. sack of natural cement to 5 sacks of standard cement. Cement factor requirements and computations shall include the natural cement.

XVI. Ready-Mixed Concrete (*widely used in metropolitan areas*).

Central-mixed or transit-mixed concrete will be permitted if it conforms to these specifications. The central plant and transporting equipment shall conform to the latest revision of A.S.T.M. Spec. C-94. *See "Data Book—Field."*

XVII. Cold-Weather Concreting.

Include only first paragraph if cold-weather concreting is not contemplated.

Concrete operations shall not be continued when the air temperature reaches 45° F. and is descending, or resumed until the air temperature reaches 40° F. and is ascending, except by written authorization of the engineer. No concrete shall be placed on a frozen subgrade at any time.

Include following requirements when concreting may be done during cold weather.

When cold-weather concreting is permitted, the aggregates and/or water shall be heated to not less than 70° F. or more than 175° F. The concrete shall have a temperature of not less than 70° F. or more than 90° F. at the time of placing.

No frozen materials shall be used in the concrete.

The subgrade shall be protected from freezing by a layer of 12 in. to 24 in. of hay or straw covered with waterproof paper or canvas.

Curing. When the average temperature is between 35° F. and 50° F. the concrete shall be covered with at least 12 in. of dry hay or straw covered with waterproof paper or canvas retained in place for 10 days.

When the air temperature reaches 35° F. and is descending, concrete laid less than 24 hr. shall be covered with an enclosure or material capable of maintaining a temperature within the concrete of not less than 60° F. or more than 100° F. for at least 7 days after placing.

Concrete Injured by Freezing shall be removed and replaced at the contractor's expense.

Accelerating or Antifreeze Admixtures shall not be used except by written permission of the engineer. In the event admixtures are permitted, no change in the methods described in this section shall be made.

Calcium Chloride. When permitted by the engineer, calcium chloride shall conform to A.S.T.M. Spec. D-98. It shall be delivered in moisture-proof bags or drums and stored in a dry place. The amount used shall not exceed 2 lb. per sack of cement. The calcium chloride may be included in the mixing water as a solution made by dissolving 1 lb. per qt. of water. The solution shall not be added in excess of 2 qt. per sack of cement.

High-Early-Strength Cement. A.S.T.M. C-150 Type III may be used only by written authorization of the engineer, at locations where speed in opening the pavement is essential.

All construction methods and materials shall conform to these specifications except that after placing of concrete a curing temperature of 70° F. shall be maintained for 48 hr. or 60° F. for 72 hr.

Payment. *Specify that adjustment in unit prices or increase in payment will* or *will not be made to the contractor for any extra cost caused by the construction methods specified for cold-weather concreting and/or the use of admixtures or high-early-strength cement.*

XVIII. Approval of Materials.

Before use, samples of all materials shall be submitted for test, and no material shall be used until approved.

Manufacturer's Certificate. (*Omit if laboratory tests are required.*) Materials may be used if accompanied by manufacturer's certificate of compliance pending any tests which may be made by the engineer. Manufacturer's certificates shall include certificate of compliance covering quality and grading of aggregates and quality of cement, joint fillers, and reinforcement and curing agents.

XIX. Tests.

Sampling. The engineer shall follow A.S.T.M. methods of sampling. *See "Data Book—Field."*

Laboratory or Plant Tests. Methods of test shall be the latest revision of the following: aggregates, water, reinforcement, cement, and curing agents. *Insert list from specifications for "Structural Concrete."*

Expansion and Joint Material		Number of Tests
Cork or rubber	A.S.T.M. D-545	One set of tests for each shipment, or each 1,000 sq. ft
Fiber	A.A.S.H.O. M-59	
Redwood	A.A.S.H.O. M-90	
Sealing compound	A.A.S.H.O. M-18	

CONCRETE CONTROL TESTS

Specimen	A.S.T.M. Designation	Purpose	Number of Specimens
Cylinders	A.S.T.M. C-31 and 39, curing and breaking	Preliminary test of mix design	4 of each mix design
		Control	3 each 2,000 sq. yd. or each day
Beams	A.S.T.M. C-78	Control	1 each 2,000 sq. yd. or each day
	Breaking, C-78, cured same as pavement slabs	Opening to traffic	2 each 2,000 sq. yd. or each day
Cores	A.S.T.M. C-42 and C-174, drilling and measuring	Pavement thickness and check on strength	2 each 1,000 lin. ft. of each lane

Field Tests. *Insert list from specifications for "Structural Concrete."* Test for air entrained in air-entrained concrete.

XX. Basis of Payment.

Specify that the contractor be paid at unit or lump sum price called for in the contract.

State work included and/or excluded under this price.

State method of measurement.

If unit price, itemize price units.

If lump sum, itemize basis of payment for extra work including the following items:

Price per square yard for concrete pavement complete in place.

Specify deductions will/or will not be allowed for areas occupied by manhole covers and other structures.

PAINTING ROAD AND AIRPORT STRIPES

I. Scope.

II. Traffic Stripes on Roads.

Center-line stripe shall be white for bituminous pavements and black for concrete pavements. The center-line stripe shall be either a solid or broken line. Barrier and no-crossing stripes shall be solid yellow. All stripes shall be 6 in. in minimum width. *See "Manual on Uniform Traffic Control, A.A.S.H.O.," for details of painting and marking.*

III. Stripes and Numerals on Airport.

Markings on runways shall be as shown on plans. *See p. 4-37 in "Data Book—Design."*

IV. Paint.

Paint for road and airfield stripes shall be in accordance with the following schedule: *Purpose; Number of Coats; General Type; Formula* or *Suggested Manufacturer's Brands.*

See "Suggestions for Specifying Paints," p. 84.

SEEDING

Use fertilizer and seed formula according to local conditions of soil and climate. This specification was used for an airport on Long Island, N. Y.

I. Scope of Work.

II. Preparation of Soil.

Before seeding or fertilizing, the topsoil surface shall be trimmed and raked to true lines free from unsightly variations, humps, ridges, or depressions.

All objectionable material shall be removed, and a finely pulverized seedbed shall be formed.

III. Fertilizing.

Superphosphate 20% shall be applied at the rate of 30 lb. per 1,000 sq. ft. and thoroughly disked into the soil to a depth of at least 4 in.

Fertilizer shall be of a brand licensed and registered with the New York State Department of Agriculture and Markets. Fertilizer shall be delivered in 100-lb. sacks.

The area to be seeded shall then be smoothed out and a $5N\text{-}10P_2O_5\text{-}5K_2O$ fertilizer shall be applied uniformly at the rate of 15 lb. per 1,000 sq. ft. The fertilizer shall be uniformly scratched into the upper inch of soil. The surface shall then be rolled with a Cultipacker.

IV. Sowing Seed.

The grass-seed formula shall be as follows:

	Per Cent by Weight	Per Cent Purity	Per Cent Germination
Kentucky blue grass	50	85	80
Domestic rye grass	40	95	90
Red top	10	90	90

Rate of sowing: 5 lb. per 1,000 sq. ft.
Weed content: maximum 1%.

The specified seed mixture shall be sown uniformly by means of mechanical distributors. The distributor shall be run over the ground as often as necessary to sow the seed at the rate specified. No seeding shall be done during windy weather or when the ground is wet or otherwise non-tillable.

The grass seed shall then be covered, using a flexible toothed weeder or other suitable equipment, by stirring the ground not deeper than $\frac{1}{4}$ in.

As soon as this covering operation has been completed, the seeded area shall be rolled again with the Cultipacker, the Cultipacker being run over the area only once, parallel with the contours of the ground.

The entire seeding operation shall be done only by experienced men.

V. Seasonal Limitations.

Seeding may be carried on from the time the ground is workable in the spring to June 1. Full advantage shall be taken of favorable weather conditions.

VI. Maintenance and Reseeding.

The contractor shall maintain all seeded areas without payment until acceptance of the contract, and any regrading, refertilizing, or reseeding shall be done at his own expense. Any areas which fail to show a "catch" or uniform stand, for any reason whatsoever, shall be reseeded with the original mixture, and such reseeding shall be repeated until final acceptance. The contractor shall properly water, mow, and otherwise maintain all seeded areas until final acceptance.

Damage resulting from erosion, gulleys, washouts, or other causes shall be repaired by filling with topsoil, tamping, refertilizing, and reseeding.

VII. Basis of Payment.

Specify that the contractor be paid at unit or lump sum price called for in the contract.

ROADWAY STRUCTURES

I. Scope.

II. Concrete Structures.

See applicable parts of specifications for "Structural Concrete," pp. 44 and 49.

III. Drainage Structures.

See applicable parts of specification for "Drainage Structures," p. 160.

IV. Bridges.

See applicable parts of specification for "Bridges," p. 139.

V. Guard Rails.

Timber shall be ____. *See "Suggested Grades and Species for Timber Specification," p. 69. Suggest same grade as for floor beams under "Bridges" and "Docks."*

Posts shall be 6 in. minimum in diameter, sound, and of species ____.

Cables shall conform to requirements of Spec. M-30 of the A.A.S.H.O. for $\frac{3}{4}$-in. Class A rope.

Fittings shall conform to the requirements of Spec. M-30 of the A.A.S.H.O.

Offset Brackets shall be of spring steel, tempered and drawn as per plan.

VI. Treatment of Posts.

Posts shall be impregnated with creosote from the bottom up to a point 8 in. above the ground. Timber shall be impregnated as follows: *See specifications for "Wood Preservation and Painting, Exposed Structures," p. 67.*

VII. Painting.

Posts shall be painted white, three coats, from a point 8 in. above the ground to the top of the post. The base of the post shall be painted black, two coats, from ground level to a point 8 in. above the ground.

Type of paint shall be the following:

See "Suggestions for Specifying Paints," p. 82.

Bark shall be removed from all posts to be treated or painted.

RAILROADS

(Engineer to submit plans and specifications to using railroads for approval.)

I. Scope of Work.

Work Included. This contract shall include preparation of site, excavating, grading, furnishing and installing drainage pipes and structures, ballast, ties, rails, and accessories as shown on plans.

II. Preparation of Site.

Specify applicable portions of specification "Preparation of Site."

III. Excavation and Grading.

Specify applicable portions of specification "Grading for Roads, Airports, and Railroads."

IV. Drainage and Drainage Structures.

All culverts under embankments shall be placed before any filling is done. All culverts under tracks shall be in place before track laying is begun. *Specify applicable portions of specifications on "Drainage Pipes, Gutters, and Ditches" and "Drainage Structures."*

V. Materials.

All materials shall conform to applicable specifications of A.R.E.A. Manual, latest edition, or specifications of using railroad, and as follows:

Ballast shall be crushed stone, gravel, cinders, or slag. (*Specify one.*) Maximum size of stone or gravel shall pass through $2\frac{1}{2}$-in. ring; minimum size shall not pass a $\frac{1}{2}$-in. ring. Gravel shall contain minimum 15%, maximum 30% sand.

Cross Ties shall be treated *or* untreated (*specify creosote treated 10 lb. to the cubic foot for permanent work*) oak *or* pine; minimum dimensions ____ in. wide by ____ in. thick by 8 ft. 6 in. long. (*Specify 8 in. wide by 6 in. thick for sidings and temporary work.*)

Switch Ties shall be treated *or* untreated (*specify treated if cross ties are treated*) oak *or* pine; minimum width ____ in., minimum depth ____ in. (*Specify 9 in. wide by 7 in. deep for siding and temporary work.*) Length to conform to frog numbers and switch numbers shown on plans.

Rails shall be new *or* relayer (*use relayer for sidings*), and shall conform to the weight shown on the plans. Relayer rail shall be free from physical defects, flat spots, wheel burns, and excessive head flow and shall be reasonably straight with fairly smooth surfaces. The rails shall be in standard lengths with not more than 10% of shorts varying in length by 1 ft. Topwear, measured at the center, shall not exceed $\frac{1}{4}$ in. Side wear shall not exceed 15% of the original dimensions.

Splice Bars, Track Bolts, and Nutlocks shall be new *or* used and of size, shape, and drilling to fit the rail.

Tie Plates shall be new *or* used and fit the base of the rail.

Track Spikes shall be cut spikes. For use with 100-lb. rail and over shall be $\frac{5}{8}$ in. by 6 in.; under 100-lb. rail, may be $\frac{9}{16}$ in. by $5\frac{1}{2}$ in.

Turnouts and Crossovers. All switches, switch stands, frogs, guard rails, etc., shall be new *or* used. (*Specify which of these items can be used and which must be new.*)

VI. Railroad-Track Construction.

Placing Ties. Ties shall be spaced as shown on plans; ties shall be laid with wider heartwood face down and normal to the center line of the track. Space shall be equidistant from rail joints and support rails at end of splice bars. One end of the ties shall be aligned. Ties shall be moved only with tongs. Ties shall not be moved or placed beneath rails with picks, mauls, sledges, or spiking hammers.

Track Laying. Rail shall be laid with staggered joints; i.e., the joints on rail shall be located as nearly as possible opposite the middle of the other rail. Temporary shims shall be used to secure proper spacing between ends of rail, and the rail temperature at the time of laying shall determine the number and thickness of shims required. Rail joints shall not be located nearer than 5 ft. from either end of a trestle or bridge.

Tie Plates shall be set in correct position on the ties, true to gage, and with shoulders in full contact with the rail. Where tie plates are not required, the rail shall make full contact with the tie.

(*Specify tie plates to be used on curves, in turnouts and crossovers, under heavy traffic, and on all treated ties.*)

Splice Bars shall be secured in place with the full number of bolts, nuts, and nutlocks. Bolts shall be staggered, with heads placed inside and outside alternately, and shall be drawn tight before spiking. After the track has been put into service, and before acceptance of the work, all bolts shall be checked and tightened as required.

Spiking. Rails shall be fully spiked promptly after laying. Spikes shall be set vertically and driven with the face of the spike in contact with the base of the rail to full bearing on the rail base.

On tangents, 2 spikes to the rail shall be used on each tie. On curves, 3 spikes to the rail for each tie shall be used, the extra spike being placed on the side of the rail facing the centerline of track. Spikes shall be staggered to avoid splitting ties. Track shall be gaged at joints, centers, and quarters as the spikes are driven, and the gage shall not be removed until the spikes are driven home. Gaging shall be accurate in all respects.

Turnouts shall conform dimensionally and be installed to the standards of American Railway Engineers' Association for the frog number used. Low switch stands shall be used and securely fastened to head blocks laid normal to the track, with targets clearly lined.

Ballasting. After track is laid ballast shall be placed to bring track to grade. If ballast is shipped in hopper cars, it may be unloaded and spread by having one or more hoppers open and allowing the required material to flow as the car moves slowly along the track. Ties or timber may be placed across the tracks in front of the car wheels just behind the open hopper to facilitate spreading.

Surfacing. After track has been ballasted, it shall promptly be brought to final grade and surfaced. Jacks for raising track shall be placed close enough together to prevent bending of the rail or strain on joints. Both rails shall be raised uniformly. All ties pulled loose shall be spiked securely in proper position with full bearing on tie plates. Each tie shall be thoroughly tamped between a point 15 in. inside each rail and the end of the tie.

Final Adjustments. Two months after the track has been accepted and put in operation, the contractor shall perform necessary resurfacing adjustments without cost to owner to leave the track in alignment and on grade.

Connections to Main-Line Tracks. (*Specify whether this contractor or others will construct main line turnouts, etc.*)

VII. Grade Crossings.

Grade crossings shall be constructed as shown on plans. Timber shall be oak, gum, *or* yellow pine, creosoted with 10 lb. per cu. ft. Paving (if used) shall be bituminous concrete. (*For composition specify applicable portions of specification for "Two-Course Bituminous Concrete Pavement."*)

VIII. Bumpers and Wheel Stops.

Bumpers and wheel stops shall be constructed as shown on plans. *(For types, manufacturers, and details, see Data Book—Design," p. 4-05.)*

IX. Cribbing.

Cribbing shall be constructed as shown on plans.

X. Clean-up.

All surplus material and trash shall be cleared from right-of-way and removed from site.

XI. Payment.

Provide clauses for payment at contract unit or lump sum price.

Provide clauses for payment at unit price or time and materials for reinforcement of soft spots in subgrade.

IV

BRIDGES

I. Scope of Work.

Work Included. This contract shall include preparation of site, excavation and grading, concrete, masonry, paving, furnishing, erecting, and painting steel structures, timberwork, piling, and all other work as shown on the plans and identified in these specifications.

Work Not Included.

II. Shop and Working Drawings.

Immediately on the award of the contract, the contractor shall prepare shop drawings of steel, timber, and concrete work based on the design drawings.

III. Excavation and Grading.

Earth Excavation. *Copy applicable portions of specification for "Excavation and Grading for Structures."*

Rock Excavation. *Copy applicable portions of specification for "Excavation and Grading for Structures."*

Grading. *Copy applicable portions of specification for "Grading for Roads, Airports, and Railroads."*

IV. Foundations and Masonry.

Stone Masonry. *Copy applicable portions of specification for "Stone Masonry."*

Concrete Masonry. *Copy applicable portions of specification for "Structural Concrete." Specify construction joints to be only as per plans; also specify ample concrete protection for reinforcement.*

Precast Concrete Cribbing. *Specify galvanized sleeves and bolts; concrete to be 28-day strength 3,750 lb. per sq. in., smooth, dense finish. Check vs. manufacturer's specifications. All reinforcement galvanized and a minimum of ____ from any surface (preferably 3 in.).*

Riprap for Slopes. *Specify nature of stone; trap rock, limestone, etc.* The stones shall be placed upon a slope not steeper than the natural angle of repose of the filling material. Stones having one broad flat surface shall be used when possible, this surface being laid on a horizontal earth bed prepared for it and so placed as to overlap the underlying course, the intent being to secure a lapped or "shingled" surface which will shed a maximum amount of water. Fifty per cent of the mass shall be of stones having a volume of 2 cu. ft. or more. These stones shall be placed first and roughly arranged in close contact. The spaces between the larger stones shall then be filled with stone of suitable size so placed as to leave the surface evenly stepped, conforming to the contour required, and capable of shedding water to the maximum degree practically obtainable. *Specify riprap to be filled with 1 : 3 mortar or grout or to be left dry.*

Stone Riprap for Foundation Protection. Stone riprap for pier and abutment protection shall range, in size, up to derrick stone and shall be graded from coarse to fine in such manner as to produce a minimum of voids. It shall be deposited where directed; stone deposited contrary to directions will be considered wasted and will not be paid for. *Where subject to ocean waves or heavy scour, specify stones from 1 to 6 tons.*

V. Waterproofing for Floors.

Waterproofing shall be 2-ply. Material shall be as follows:

Primer	A.S.T.M. D-41
Coal-tar pitch	A.S.T.M. 450 Type A (below ground) *or* B (above ground)
Fabric	A.S.T.M. D-173-42
Seal-coat asphalt	A.S.T.M. D-449 Type A (below ground) *or* B (above ground)
Tar	Specification M-52, Grade RTCB-5, A.A.S.H.O. Standard Specifications for Highway Materials

Preparation of Surface. All concrete surfaces which are to be waterproofed shall be reasonably smooth, and free from projections or holes which might cause puncture of the membrane. The surface shall be dry, so as to prevent the formation of steam when the hot asphalt or tar is applied, and, immediately before the application of the waterproofing, the surface shall be thoroughly cleaned of dust and loose materials.

No waterproofing shall be done in wet weather or when the temperature is below 35° F.

Damp surfaces may be artificially dried if approved by the engineer.

Application. Asphalt shall be heated to a temperature between 300 and 350° F., and tar for hot application shall be heated to a temperature between 200 and 250° F., with frequent stirring to avoid local overheating. The heating kettles shall be equipped with thermometers.

Beginning at the low point of the surface to be waterproofed, a coating of primer shall be applied and allowed to dry before the first coat of asphalt is applied.

The completed waterproofing shall be a firmly bonded membrane composed of two layers of fabric and three moppings of asphalt or tar, together with a coating of primer. Under no circumstances shall one layer of fabric touch another layer at any point or touch the surface, as there must be at least three complete moppings of asphalt or tar.

On horizontal surfaces not less than 12 gal. of asphalt or tar shall be used for each 100 sq. ft. of finished work, and on vertical surfaces not less than 15 gal. shall be used.

The work shall be so regulated that, at the close of a day's work, all cloth that is laid shall have received the final mopping of asphalt or tar. Special care shall be taken at all laps to see that they are thoroughly sealed down.

Joints which are essentially open joints but which are not designed to provide for expansion shall first be calked with oakum and lead wool and then filled with hot joint filler.

Expansion joints, both horizontal and vertical, shall be provided with sheet copper or lead in "U" or "V" form in accordance with the details and, after the membrane has been placed, shall be filled with hot joint filler. The membrane shall be carried continuously across all expansion joints. At the ends of the structure, the membrane shall be carried well down on the abutments, and suitable provision shall be made for all movement.

Flashing, wherever shown on plans, shall be 16 oz. copper lapped 8 in. between upper and lower ply.

Protection Course. Over waterproofing membrane, constructed as specified above, a protection course shall be constructed which shall be a 2-in. course of mortar mixed in the proportion of 1 part Portland cement and 2 parts sand. This mortar course shall be reinforced midway between its top and bottom surfaces with wire netting of 6-in. mesh and No. 12 gage, or its equivalent. The top surface shall be troweled to a smooth, hard finish and, where required, true to grade.

The construction of the protection course shall follow the waterproofing so closely that the waterproofing will not be exposed without protection for more than 24 hr.

VI. Timber Work.

Material. *Specify species and stress grades to conform with design stresses and usage; see "Suggested Grades and Species for Timber Specification," p. 69.*

Untreated Timber. In structures of untreated timber the following surfaces shall be thoroughly coated with two coats of hot creosote oil before assembling: ends, tops, and all contact surfaces of sills, caps, floor beams, and

stringers; and all ends, joints, and contact surfaces of bracing and truss members. The back faces of bulkheads and all other timber which is to be in contact with earth, metal, or other timber shall be similarly treated.

Preservatives. Copy applicable portions of specification for "Wood Preservation and Painting, Exposed Structures," p. 67.

All timber shall be treated with creosote except surface decking, railing, wheel guards, and sidewalks.

Piles. To specify piles, copy applicable portions of specification for "Piling," p. 33. Also see "Suggested Grades and Species for Timber Specification," p. 69.

Tops of piles shall be protected with cap of 8-oz. duck and red lead as per detail on drawings.

Hardware. Machine bolts, drift bolts, and dowels may be either wrought iron or medium steel. Washers may be cast O-gee or malleable castings, or they may be cut from medium steel or wrought iron plate as indicated. Bolts passing through non-resinous wood shall be galvanized. Machine bolts shall have square heads and nuts, unless otherwise indicated. Nails shall be cut or round wire of standard form. Spikes shall be cut or wire spikes, or boat spikes.

Nails, spikes, bolts, dowels, washers, and lag screws shall be black or galvanized, in accordance with A.S.T.M. 153-42T.

Unless otherwise indicated, all hardware, except malleable-iron connectors, for treated timber bridges, shall be galvanized or cadmium plated.

Connectors, if shown on the plans, shall be installed in accordance with the manufacturer's recommendations.

Construction.

Pile Driving. Copy applicable portions of specification for "Piling."

Holes for Bolts, Dowels, Rods, and Lag Screws. Holes for round drift bolts and dowels shall be bored with a bit $\frac{1}{16}$ in. less in diameter than the bolt or dowel to be used. The diameter of holes for square drift bolts or dowels shall be equal to the least dimension of the bolt or dowel.

Holes for machine bolts shall be bored with a bit of the same diameter as the bolt.

Holes for rods shall be bored with a bit $\frac{1}{16}$ in. greater in diameter than the rod.

Holes for lag screws shall be bored with a bit not larger than the body of the screw at the base of the thread.

Bolts and Washers. Unless shown otherwise on the drawings, a washer of the standard size and type shall be used under all bolt heads and nuts which would otherwise come in contact with wood.

Countersinking shall be done wherever smooth faces are required. Horizontal recesses formed for countersinking shall be painted with hot creosote oil and, after the bolt or screw is in place, shall be filled with hot pitch.

Framing. All lumber and timber shall be accurately cut and framed to a close fit in such manner that the joints will have even bearing over the entire contact surfaces. Mortises shall be true to size for their full depth, and tenons shall fit snugly. No shimming will be permitted in making joints, nor will open joints be accepted.

Floors. Plank floors shall be surfaced one side and one edge. The planks shall be laid heart side down, with $\frac{1}{4}$-in. openings between them for seasoned material and with tight joints for unseasoned material. Each plank shall be securely spiked to each joist. The planks shall be carefully graded as to thickness and so laid that no two adjacent planks shall vary in thickness by more than $\frac{1}{16}$ in.

Two-ply timber floors shall consist of two layers of flooring supported on stringers or joists. The top course may be laid either diagonal or parallel to the center line of the roadway, as specified, and each floor piece shall be securely fastened to the lower course. Joints shall be staggered at least 3 ft. If the top flooring is placed parallel to the center line of the roadway, special care shall be taken to fasten the ends of the flooring securely. At each end of the bridge these members shall be beveled.

Laminated or strip floors. The strips shall be placed on edge, at right angles to the center line of the roadway. Each strip shall be spiked to the preceding strip at each end and at approximately 18-in. intervals with the spikes

driven alternately near the top and bottom edges. The spikes shall be of sufficient length to pass through two strips and at least halfway through the third strip.

If timber supports are used, every other strip shall be toenailed to every other support. The size of the spikes shall be as shown on the plans. When specified on the plans, the strips shall be securely attached to steel supports by means of approved galvanized-metal clips. Care shall be taken to have each strip vertical and tight against the preceding one, and bearing evenly on all supports.

Trusses. Trusses, when completed, shall show no irregularities of line. Chords shall be straight and true from end to end in horizontal projection and, in vertical projection, shall show a smooth curve through panel points conforming to the correct camber. All bearing surfaces shall fit accurately. Uneven or rough cuts at the points of bearing shall be cause for rejection of the piece containing the defects.

Painting. Copy applicable portions of specification for "Wood Preservation and Painting, Exposed Structures," p. 67.

VII. Structural Steel.

Material. (*See design.*)

Steel shall be structural carbon steel, A.S.T.M. A-7; *or* structural silicon, A.S.T.M. A-94; *or* structural nickel, A.S.T.M. A-8. Rivet steel shall be A.S.T.M. A-141.

Expansion plates and bearing plates shall be of structural steel or bronze. Bronze shall be A.S.T.M. B-22, Class B.

Select paint as per "Suggestions for Specifying Paints," p. 81. Paint shall be furnished in standard containers ready mixed. Manufacturer shall furnish a certificate guaranteeing that the paint furnished fulfills the federal specification called for.

Fabrication of the steel shall be in accordance with the latest A.A.S.H.O. Standard Specifications for Highway Bridges.

Erection. Work shall be erected in accordance with the latest A.A.S.H.O. Standard Specifications for Highway Bridges. The following are excerpts from the 1944 edition which will govern in case of differences.

Falsework shall be furnished under this heading. The falsework shall be properly designed and substantially constructed and maintained for the loads which will come upon it. The contractor, if required, shall prepare and submit to the engineer, for approval, plans for falsework or for changes in an existing structure necessary for maintaining traffic.

Bearing and Anchorages. Bearing plates shall be set level in exact position and shall have a full and even bearing upon the masonry. They shall be placed on a layer of canvas and red lead or sheet lead as per details on drawings. The contractor shall drill the holes and set the anchor bolts. The bolts shall be set accurately and fixed with Portland cement grout completely filling the holes. The location of the anchor bolts in relation to the slotted holes in the expansion shoes shall correspond with the temperature at the time of erection. The nuts on anchor bolts at the expansion ends of spans shall be adjusted to permit the free movement of the span.

Straightening Bent Material. The straightening of plates and angles or other shapes shall be done by methods not likely to produce fracture or other injury. The metal shall not be heated unless permitted by the engineer, in which event the heating shall not be to a higher temperature than that producing a dark "cherry-red" color. After heating, the metal shall be cooled as slowly as possible. After the straightening of a bend or buckle, the surface of the metal shall be carefully inspected for evidence of fracture.

Assembling Steel. Hammering which will injure or distort the members shall not be done. Bearing surfaces and surfaces to be in permanent contact shall be cleaned before the members are assembled. Unless erected by the cantilever method, truss spans shall be erected on blocking so placed as to give the trusses proper camber. Rivets in splices of butt joints of compression members and rivets in railings shall not be driven until the span has been swung. Splices and field connections shall have one half of the holes filled with bolts and cylindrical erection pins (half bolts and half pins) before riveting. Fitting-up bolts shall be of the same nominal diameter as the rivets, and cylindrical erection pins shall be $\frac{1}{32}$ in. larger.

Riveting. Pneumatic hammers shall be used for field riveting, except when the use of hand tools is permitted by the engineer. Connections shall be accurately and securely fitted up before the rivets are driven. Drifting shall be only such as to draw the parts into position and not sufficient to enlarge the holes or distort the metal. Unfair holes shall be reamed or drilled. Rivets shall be heated uniformly to a light "cherry-red" color and shall be driven while hot. They shall not be overheated or burned. Rivet heads shall be full and symmetrical, concentric with the shank, and shall have full bearing all around. They shall not be smaller than the heads of the shop rivets. Rivets shall be tight and shall grip the connected parts securely together. Calking or recupping will not be permitted. In removing rivets, the surrounding metal shall not be injured; if necessary, they shall be drilled out.

Bolted Connections. In bolted connections, the nut shall be drawn up tight and set by center-punching the threads of the bolt at the face of the nut.

Pin Connections. Pilot and driving nuts shall be used in driving pins. They shall be furnished by the contractor without charge. Pins shall be so driven that the members will take full bearing on them. Pin nuts shall be screwed up tight and the threads burred at the face of the nut with a pointed tool.

Misfits. Minor misfits may be corrected at the site only with the consent and during the presence of the engineer.

Painting shall be done in accordance with the latest A.A.S.H.O. Standard Specifications for Highway Bridges. The following are excerpts from the 1944 edition which will govern in case of differences. Give schedule of brands, formulas, or allowances for different parts of the work. *See "Suggestions for Specifying Paints," p. 81.*

Number of Coats and Colors. All steel shall be painted with one shop or prime coat, and with two field coats, as specified below. The color shall be as specified or determined by the engineer.

Mixing of Paint. Paint shall be factory mixed. All paint shall also be field mixed before application in order to keep the pigments in uniform suspension.

Weather Conditions. Paint shall not be applied when the air temperature is below 40° F. It shall not be applied upon damp or frosted surfaces. Painting shall not be done when the metal is hot enough to cause the paint to blister and produce a porous paint film.

Thinning Paint. Paint as delivered in containers when thoroughly mixed is ready for use. If in cool weather paint does not spread freely, it shall be treated only by heating in hot water or on steam radiators, and liquid shall not be added or removed unless permitted by the engineer.

Cleaning of Surfaces. Surfaces of metal to be painted shall be thoroughly cleaned to remove rust, loose mill scale, dirt, oil or grease, and other foreign substances.

Field Painting. The following provision shall apply to the application of both field coats. To secure a maximum coating on edges of plates or shapes, rivet heads, and other parts subjected to special wear and attack, the edges shall first be striped with a longitudinal motion and the rivet heads with a rotary motion of the brush, followed immediately by the general painting of the whole surface, including the edges and rivet heads.

If, in the opinion of the engineer, traffic produces an objectionable amount of dust, the contractor shall, at his own expense, allay the dust for the necessary distance on each side of the bridge and take any other precautions necessary to prevent dust and dirt from coming in contact with freshly painted surfaces or with surfaces before the paint is applied.

The application of the second field coat shall be deferred until adjoining concrete work has been placed and finished. If concreting operations have damaged the paint, the surface shall be recleaned and repainted.

The contractor shall protect pedestrian, vehicular, and other traffic upon or underneath the bridge, and also all portions of the bridge superstructure and substructure, against damage or disfigurement by spatters, splashes, and smirches of paint or paint materials.

Name Plate. *Specify bronze or other material for plate as per detail; also specify that no other name is to appear without permission of the engineer.*

VIII. Paving.

See paving specifications under "Airports, Roads and Railroads," and copy parts applicable.

IX. Cleaning Up.

Write suitable clauses for cleaning up, including removal of falsework and old structures and restoration work.

X. Field Tests.

Check on manufacturer's paint certificate.

Take samples of paint for analysis.

See also laboratory and field tests for component structural materials under the separate specifications incorporated in this volume.

V

DOCKS

I. Scope.

Work Included. This contract shall include construction of wooden pier, power line, lighting, dredging, and all other work as shown on the plans.

Work Not Included.

II. Workmanship.

Special care shall be exercised whenever one timber laps or abuts or crosses another. The surfaces in contact, all cut surfaces, and all heads of piles before placing timbers shall be liberally coated with creosote oil; all bolt holes and countersunk holes shall be similarly coated with creosote oil and thereafter completely filled with hot molten pitch or other suitable material approved by the engineer. The creosote oil shall conform to Fed. Spec. TT-W-560. All bolt holes shall be $\frac{1}{16}$ in. larger than the diameter of the bolt. All dock spikes shall be driven through round holes bored through the timbers to prevent splitting. These holes shall be of the same diameter as the nominal size of the spikes.

III. Working Drawings.

Working drawings based on the design drawings shall be submitted to the engineer, for his approval, for fittings, miscellaneous iron work, ______________________________.

IV. Piles.

Material. See *"Suggested Grades and Species for Timber Specification," p. 69.*

Wood Piles shall be sound and free from sharp crooks or bends or decay and sufficiently straight so that a line drawn from the center of the head to the point will be wholly within the pile. The diameter at the point shall not be less than 7 in. for piles up to 40 ft. in length and not less than 6 in. for piles longer than 40 ft. At a point 2 ft. 0 in. from butt, piles less than 25 ft. 0 in. long shall have a minimum diameter of 10 in.; piles over 25 ft. 0 in. long shall have a minimum diameter of 12 in. All measurements shall be made under bark.

Piles shall *or* shall not be treated. *Specify as per "Wood Preservation and Painting, Exposed Structures," p. 67.*

Fender Piles shall be mixed oak.

Driving. Piles shall be driven as shown on the plans. Pile rows shall be additionally secured by means of brace piles driven at an inclination as shown and properly secured to the piles and to the timbers as shown on the plans. All piles shall be peeled.

Piles shall be driven with a drop hammer or with a single-acting steam hammer of Vulcan type with weight of the striking part of the hammer times its fall at least 15,000 ft-lb. to a safe bearing value of ____ tons, or to refusal for piles driven to rock or hardpan. The double-acting steam hammer of the Standard McKiernan-Terry type may be used when driving piles to refusal but shall not be used for other piles except with special permission of the engineer.

The ratio of the weight of pile F and the weight of the striking part of the hammer W shall be between the following limits:

$$\frac{F}{W} = \frac{1}{10} \text{ minimum to } \frac{F}{W} = 10 \text{ maximum}$$

The safe value of piles shall be determined by the following formula:

$$P = \frac{2WH}{S+1} \text{ for drop hammer}$$

$$P = \frac{2WH}{S+0.1} \text{ for single-acting steam hammer}$$

$$P = \frac{2(W+Ap)H}{S+0.1} \text{ for double-acting steam hammer}$$

where P = safe load in pounds, W = weight of the striking part of the hammer in pounds, H = the fall in feet of the striking part of the hammer or stroke, S = average penetration per blow in inches under the last five blows, A = area of piston in square inches, and p = mean effective steam pressure.

Driving shall be done with fixed leads which will hold the pile firmly in position and alignment and in axial alignment with the hammer.

Driving of all piles shall be continuous without intermission until pile has been driven to final resistance. Tops of piles shall be cut off true and level at the elevations indicated on drawings.

The brace piles shall be driven with a hammer of the same weight as that used in driving the vertical piles. Allowance shall be made in the effective fall of the hammer to compensate for the canting of the leads. Special rigid inclined guiding leads of an approved design shall be provided for the driving of the brace piles if so directed.

The contractor shall mark the pile driver ways legibly with paint at intervals of 1 ft.

Records. The contractor shall keep a record of each pile driven and furnish signed typewritten copies daily. The records shall give the diameters, length, location, type, penetration under the last five blows of the hammer, and result of any tests.

Damage. Broken or shattered piles will not be accepted. Piles shall be not more than 2% out of plumb and not more than 3 in. out of place. Should any pile be damaged by overdriving or not conform to the tolerances of the specifications, an extra pile or piles shall be driven in its place. Piles rejected after driving may remain in the ground or be removed at the discretion of the engineer.

Obstructions. Where boulders or other obstructions make it impossible to drive certain piles in location snown and to proper bearing strata, the contractor shall resort to all usual methods to install piles as required, including spudding, jetting, or other feasible means. *Specify the cost of jetting, spudding, etc., as an extra or without cost to owner as desired.* If, in the judgment of the engineer, the contractor is unable to complete properly any pile by resorting to such methods, the engineer may order an additional pile or piles driven for which the contractor will be paid in accordance with unit prices in the contract. Where directed by the engineer, excavation operations shall be conducted to remove obstructions at the owner's expense as covered in Section IX, "Basis of Payment."

Lagging. Wherever shown on drawings or requested by the engineer, piles shall be lagged to increase resistance as per detail shown on drawings.

Stay Lathing. The pile rows shall be straightened and stay-lathed as directed by the engineer, as soon as the piles in one row are driven, and before they are cut off to grade.

V. Timberwork.

Material. Grade shall conform to the grading rules of the association under which the lumber is produced. It shall bear the grade and trademark of this association and a mark of mill identification. Material shall be as follows: *See "Suggested Grades and Species for Timber Specification," p. 69.*

Deck Sheathing.

Under Decking.

Caps, Rangers, and Stringers.

Preservatives. All timber except backing logs, decking, sheathing, fender caps, fender chocks, and fenders shall be treated with creosote. *Specify as per "Wood Preservation and Painting, Exposed Structures," p. 67.*

Erection.

Framing and Bolt Holes. All timbers, whenever possible, shall be cut to size and holes shall be bored before creosoting. Cutting made subsequently shall be painted with hot creosote oil. All preservatives shall be in accordance with the current American Wood Preservers Association's standard specifications for preservative treatment by pressure process.

Caps and Clamps. The heads of piles of the "double rows" shall be held and secured in place by means of one 10 in. by 12 in. cross cap and by two 6 in. by 12 in. clamps; the heads of the piles shall be carefully trimmed beforehand to obtain tenons about 8 in. thick, and said cap and clamps, resting on the shoulders, shall be thus secured by means of $1\frac{1}{8}$-in. machine bolts, all as shown.

The heads of the piles of the "single rows" shall be similarly held in place by means of two 6 in. by 12 in. clamps, secured to the tenons by 1-in. machine bolts.

All bolt fastenings shall have two washers and shall be drawn tightly together.

Horizontal and Diagonal Braces. In addition to the clamps, the pile rows shall be further held in place by means of 4 in. by 10 in. horizontal and diagonal braces; these braces shall be fastened to the piles by means of bolts or dock spikes, as shown. Should the spikes stand off from the braces, the piles shall be chamfered slightly to enable proper chocks to be inserted between the pile and the braces; these chocks shall be not less than 2 in. thick and not less than 12 in. long.

Rangers. Continuous lines of ____ in. by ____ in. timbers called rangers shall extend from the outer "double" row of the pier to the concrete abutment as shown on the plans; they shall be in single lengths butting against each other and joined by means of two 6 in. by 10 in. fishplates with four 1-in. machine bolts for each joint; these rangers shall be notched over the pile rows, as shown; they shall break joints at alternate lines and shall be secured at each crossing of a pile head with one $\frac{7}{8}$ in. by 26 in. dock spike and at each crossing of a cross cap of the "double rows" by means of one $\frac{3}{4}$ in. by 22 in. dock spike, all as shown on the drawings.

Side Cap. The side piles shall be held in place by side caps of 12 in. by 12 in. timbers secured by means of scarf joints as shown. The side caps shall be fastened to the piles by means of one $\frac{7}{8}$ in. by 26 in. dock spike at each crossing.

Deck Sheathing of 3 in. by 10 in. planking, dressed on one side and on two edges, shall be placed over the underflooring diagonally as shown. The diagonal strips shall consist of strakes of not more than ____ lengths, breaking joints in alternate strakes. The planks, if seasoned, shall be laid with spaces of $\frac{1}{2}$ in. between them. Each plank shall be fastened at each end with two and at crossing of a ranger with one $\frac{1}{2}$ in. by 8 in. dock spike.

The underfloor shall be 4 in. thick, spaced and fastened as above.

Backing Log. On each side of the pier and at the outer end, where shown, a backing log of 12 in. by 12 in. timber shall be laid in single lengths of about 22 ft.; they shall be joined by means of half laps, about 2 ft. long, as shown. The backing logs shall be secured to the rangers, through the fillers, by means of one 1-in. bolt, at about every 4 ft., countersunk on top.

Fender System. The sides and outer end of the pier shall be protected by a fender system consisting of vertical fender piles and fender chocking and of clusters of piles, all as shown and indicated on the drawings.

Fender Piles shall conform to the requirements of timber piles hereinbefore described. They shall be properly secured in place by means of machine bolts, countersunk on the outside; the clusters shall be additionally secured by means of three turns of $\frac{3}{4}$-in. steel cables, notched into the piles, and secured to the piles and adjacent timbers by means of 5-in. galvanized-iron staples, all as shown and directed.

Fender Chocks. Top and bottom fender chocks of 8 in. by 10 in. timbers shall be used to further secure the fender piles in place. The fender chocks shall be secured to the backing log or rangers and side caps by means of bolts, as shown. The outside of the bolts shall be properly countersunk.

Bolts, etc. All iron such as bolts, nuts, washers, spikes, and pipe sleeves shall be hot-dipped galvanized wrought iron. All bolts and nuts must be threaded before galvanizing. Galvanizing shall be in accordance with A.S.T.M. 153-42T. Washers for 1-in. bolts shall be $3\frac{1}{4}$ in. in diameter by $\frac{1}{4}$ in. thick; for $1\frac{1}{8}$-in. bolts they shall be $3\frac{5}{8}$ in. in diameter by $\frac{3}{8}$ in. thick; for $1\frac{1}{4}$-in. bolts, except where otherwise indicated, they shall be 4 in. in diameter by $\frac{1}{2}$ in. thick.

VI. Fittings.

Bitts, chocks, and cleats for mooring purposes shall be provided as shown on the plans and as per details given on the plans, and shall be of cast iron.

All cast iron used in the work shall conform to all the requirements of the Standard Specifications for Gray Iron Castings of the American Society for Testing Materials, Serial No. A-48-36, Class 35.

VII. Painting.

Specify as per "Suggestions for Specifying Paints," p. 80.

VIII. Tests.

At Source.

Galvanizing, A.S.T.M. 153-42T.

Preservatives. Timber and piles treated shall be inspected and tested before and after treatment at the plant. The tests for inspection of the preservative treatment of wood shall be in accordance with the American Wood Preservers Association, Standard Instructions 33B. Material shall bear inspection stamp or seal.

Field Inspection. *Check on grade mark and quality of timber.*

IX. Basis of Payment.

Specify that the contractor shall be paid for work within limits shown on plan by lump sum or unit costs given in contract.

The contractor shall include in his bid unit prices for the following:

Increase and decrease of the number of piles shown on drawings, quoting a price per pile.

Increase and decrease of total length of piling shown on drawings, quoting a price per linear foot.

Use of pile driver for extra work like spudding and jetting, quoting a price per hour.

Cost of lagging piles, quoting a price per linear foot.

Specify that, where obstructions require, the contractor shall excavate or use different types of piles, on a time and material basis agreed upon in the contract.

VI

DAMS

(It is assumed that the engineer has designed the dam of either earth fill or concrete, or both, and that the embankment requirements may be met from local borrow pits.)

I. Scope.

Work Included. *General description including* "and all other work as shown on the plans and included in the specifications."

Work Not Included. *Description of items definitely excluded from the contract.*

II. Shop Drawings.

Shop drawings based on the design drawings for reinforced concrete, structural steel, ashlar, masonry, and all equipment such as flood gates and special valves shall be submitted to the engineer for his approval.

III. Cofferdams and Unwatering.

The contractor shall construct and maintain all necessary cofferdams, channels, flumes, and/or other temporary diversion and protective works; shall furnish all materials required therefor; and shall furnish, install, maintain, and operate all necessary pumping and other equipment for unwatering the various parts of the work, and for maintaining the foundation, cut-off trenches and other parts of the work free from water as required for constructing each part of the work. Locations of cofferdams are shown on the drawings. Plans for cofferdams and other diversion works showing type and sequence of construction, elevations, etc., and any proposed changes in location shall be submitted to the engineer for approval. River discharge curves and diversion works capacity curves are shown on the drawings solely for the purpose of aiding the contractor to time his construction operations to prepare for such flood storage and/or bypass such flow as may be necessary. The reliability or accuracy of any of these curves is not guaranteed. After having served their purpose, all cofferdams and other temporary protective works downstream from the dam shall be removed from the river channel or leveled to give a sightly appearance, so as not to interfere in any way with the operation or usefulness of the reservoir. All cofferdams or other temporary protective works constructed upstream from the dam shall be removed to the extent required to prevent obstruction in any degree whatever of the flow of water to the outlet works.

IV. Embankment.

Embankment Construction, General. The term "embankment" shall include the earth-fill portion of the dam and the riprap on the upstream face of the dam. The embankment shall be constructed to the lines and grades shown on the drawings. The contractor shall allow for ___% of shrinkage and include this amount in his bid. No brush, roots, sod, or other perishable or unsuitable materials shall be placed in the embankment. The suitability of each part of the foundation for placing embankment materials thereon, and of all materials for use in the embankment construction, will be determined by the engineer. No material shall be placed in the embankment when either the material or the foundation or embankment on which it would be placed is frozen.

Earth Fill in Embankment. The earth-fill portions of the dam, including the fill in the cut-off trench under the upstream portion of the dam, shall consist of a soil with the physical characteristics given below. While in general this gradation fits local sources, it is contemplated that it will be necessary to improve the natural borrow by selection and mixing as described below. A scientific control covering moisture determination, grain-size analysis, and density measurement is contemplated, and the contractor will be expected to conduct his operations accordingly.

No material shall be placed in the earth-fill portion of the dam until after the diversion of the river has been accomplished, except as may be approved by the engineer. No earth-fill material shall be placed until the foundation therefor has been unwatered and suitably prepared. The distribution and gradation of materials throughout the earth-fill portions of the dam shall be such that the earth embankment will be free from lenses, pockets, streaks, or layers of material differing materially in texture or gradation from the surrounding material.

The mixture of clay, sand, and gravel, bank run or pre-mix, shall be placed in the earth embankment in continuous, approximately horizontal, layers not more than 6 in. in thickness after rolling. Tamping rollers having staggered, uniformly spaced knobs and equipped with suitable cleaners shall be used for compacting the earth fill. The projected face area of each knob and the number and spacing of the knobs shall be such that the total weight in pounds of the roller and ballast, if distributed over the equivalent area of one row of knobs parallel to the axis, shall not be less than 250 lb. per sq. in.

The material in each layer while being compacted by rolling shall contain optimum moisture for maximum density for compacting purposes within practicable limits, and this optimum water content shall be uniformly distributed throughout the layer. The application of water to material for this purpose shall be done at the site of excavation as far as practicable and shall be supplemented as required by sprinkling on the embankment. Harrowing or other working of the material may be required to produce uniformity of water content. While in the above-described condition, each layer of material shall be compacted by passing the specified roller over the entire surface the number of times required as follows: Finished embankment shall be compacted to not less than 95% of the dry densities which correspond to optimum moisture for the soil and as determined by the engineer.

All portions of test-pit and cut-off trench excavation within the area to be covered by the embankment and below the required stripping lines for the embankment foundation shall be filled with compacted embankment material as herein specified for the earth fill. The earth fill on each side of the cut-off walls shall be kept at approximately the same level as the placing of the earth fill progresses, and the walls shall be carefully protected against displacement or other damage. Portions of the earth fill between projections on the dam abutments, near the cut-off walls, which cannot be properly compacted by means of rolling equipment, shall be thoroughly compacted by means of mechanical tampers. The degree of compaction for such portions of the earth fill shall be equivalent to that obtained by moistening and rolling as specified for other portions of the earth fill. The upstream face of the earth fill shall be reasonably true to line and grade, and all projections of more than 6 in. outside the neat lines of the earth fill shall be removed before the rock riprap is placed. The upper 12 in. of the crest of the dam embankment shall be constructed of selected gravelly material or selected fine-rock material.

Embankment Material Including Core. *Specify gradation limits, i.e., effective size and uniformity coefficient limit, for different sections of embankment. See pp. 4-74 and 3-24, "Data Book—Design."*

Non-Plastic Material. Where the material as desposited in 6-in. layers does not fulfill the above requirements, finer or coarser material as required shall be added and thoroughly mixed with the layer below by harrows, blade graders, rotary tillers, or by other means, to the satisfaction of the engineer.

Plastic Material. Where plastic material is required to be added or where granular material is required to be added to plastic material, it shall be spread in thin layers not over 3 in. and mixed with a sheepsfoot roller, plus blade-grading and harrowing.

Reverse Filter shall be constructed as shown on plan. It shall consist of three 12-in. layers of progressively coarser material compacted by rolling and graded as follows:

First layer shall be fine sand with a 15% size of ____.
Second layer shall be coarse sand with a 15% size of ____.
Third layer shall be gravel with a 15% size of ____.

Note. For guidance in specifying the 15% size, see p. 4-76, "Data Book—Design."

Riprap. *See applicable portions of specification for "Bridges."*

V. Concrete.

See applicable portions of specification for "Structural Concrete." Specify use of A.S.T.M. C-150, Type IV, low-heat cement.

Setting. The operations shall be so carried on that the internal heat during setting will not exceed ____°.

Construction Joints shall be built only where shown on plans and shall have V joints at the exposed surface. In all cases the surface of the concrete shall be cleaned of laitance, roughened, and painted with grout before the adjacent concrete is poured, *or* surfaces shall be treated to prevent bonding. (*Specify.*)

A 16-oz. copper water stop, as per plans, shall be provided.

Dowels shall be provided where called for on plans.

Unwatering Forms. All concrete shall be placed in the dry.

VI. Grouting.

Pervious rock foundation under dams and above dams should be grouted to prevent the flow of water.

Where directed by the engineer, rock shall be grouted.

The location of grout holes and depths shall be as directed by the engineer.

Grout shall be placed at pressures up to 100 lb. per sq. in. as required.

Grout shall be composed of cement and water, except that for very open seams sand shall be introduced into the mixture.

Grouting machinery used shall be subject to the approval of the engineer.

VII. Rock Fill.

The rock fill shall consist of a suitable free-draining mixture of rock fragments, boulders, or cobbles. The largest rock in the rock fill shall be not more than 1 cu. yd. in volume. The inclusion of gravel or rock spalls in the mass in an amount not in excess of that required to fill the voids in the coarser material shall be required. The larger stones shall be placed on the downstream slope and the smaller stones next to the upstream blanket. The rock fill shall be placed in approximately horizontal layers not exceeding 3 ft. in thickness but well bonded between layers, and during the placing of each layer the fine material shall be sluiced into the voids in the rock by a stream of water having sufficient force to move the material in place. The materials need not be hand placed, but there shall be no unfilled spaces within the fill.

VIII. Preparation of Foundation.

Foundation for Earth Fill. After all necessary stripping and excavation have been completed, the foundation area shall be unwatered and the foundation for the earth fill shall be so prepared by scraping and rolling that the surface materials of the foundation are as compact and well bonded with the first layer of the fill as is specified for the subsequent layers of the earth fill.

Note. Specifications for the preparation of foundations for rock-fill dams and for concrete structures on formations other than rock are determined by local conditions.

Foundation on Rock for Concrete. The surfaces of all rock foundations upon or against which concrete is to be placed shall be prepared to provide adequate bond between the rock and the concrete by roughening and cleaning the rock surfaces. All loose rock fragments, spalls, dirt, gravel, grout, and other objectionable materials shall be removed from the rock surfaces. Immediately before concrete is placed upon or against any rock surface, the surface shall be thoroughly cleaned by means of stiff brooms, hammers, picks, jets of water and air applied at high velocity, wet sandblasting, or other effective means satisfactory to the engineer. After cleaning and before concrete is placed, all water shall be removed from depressions so as to permit thorough inspection and proper bond of concrete with the foundation rock.

Stripping for Embankment. The entire areas of the dam and dike sites, including the areas over cut-off trenches, shall be stripped or excavated to a sufficient depth to remove all materials not suitable, as determined by the engineer, for the foundations. The unsuitable materials to be removed shall include top soil, all rubbish, vegetable matter of every kind, roots, and all other perishable or objectionable materials which might interfere with the proper compacting of the materials in the embankments or be otherwise objectionable. The stripped materials shall be wasted or saved for landscaping.

IX. Blanket for Rock Fill.

Specify impervious earth fill or blanket of timber or concrete, as per plan.

X. Permanent Equipment.

The outlet gates, frames and hoists, trash racks, ladders, rungs, floor plates, and pipe handrail materials and other metal work required as parts of the completed structure shall be furnished by the contractor. The contractor shall attach to or build into the dam or appurtenant works all such metal work and shall install the gates and hoists in a workmanlike manner, as shown on the drawings or as directed. All moving parts and control mechanisms shall be carefully installed, tested for operation, and adjusted so that all parts move freely as intended and function properly to secure satisfactory operation. Any changes or adjustments required shall be made to secure satisfactory operation.

XI. Piping and Valves.

See applicable portions of specification for "Water Distribution System."

XII. Painting.

For metal, copy applicable portions of "Suggestions for Specifying Paints."

For timber preservation and painting, copy applicable portions of specification for "Wood Preservation and Painting, Exposed Structures."

XIII. Basis of Payment.

Specify lump sum.

Give unit prices for extra earth and rock excavation and embankment below lines shown on plans.

Rock grouting per cubic foot.

Extra steel and/or wood sheath piling, per square foot.

Extra pumping, on basis of time and material.

VII

DRAINAGE, SEWERS, SEWAGE TREATMENT, AND WATER

EXCAVATION, TRENCHING, AND BACKFILLING FOR UTILITY SYSTEMS

I. Scope of Work.

Work under this section shall consist in furnishing all materials, equipment, and labor for excavation, trenching, and backfilling for utility systems. "Utility systems" shall include underground piping and appurtenances for gas, gasoline, oil, and water distribution systems, storm water drains, and sewage collection systems.

II. Stripping of Topsoil, Seeding, Sodding, etc.:

Specify as required for job. See applicable portions of specification for "Grading for Roads, Airports, and Railroads."

III. Excavation.

General. The contractor shall do all excavation of whatever substances encountered to depth shown on plans. Excavated materials not required for fill or backfill shall be removed from site as directed by the engineer.

Excavation for manholes and other accessories to have 12-in. minimum and 24-in. maximum clearance on all sides.

Excavation shall not be carried below the required level.

Excess excavation below required level shall be backfilled at the contractor's expense with earth, sand, gravel, or concrete, as directed by the engineer, and thoroughly tamped.

Unstable soil shall be removed and replaced with gravel, crushed stone, or crushed slag, which shall be thoroughly tamped. The engineer shall determine the depth of removal of unstable soil.

Specify that the contractor will or *will not be paid extra for removing unstable soil and replacing with gravel.*

Ground adjacent to all excavations shall be graded to prevent water running in.

The contractor shall remove, by pumping or other means approved by the engineer, any water accumulated in excavation.

Specify pumping to be or *not to be paid for extra.*

Trench Excavation. Banks of trenches shall be vertical.

Width of Trench shall be 6 in. minimum, 8 in. maximum, on each side of the pipe bell. The bottom of trench for sewers and culverts shall be rounded so that an arc of the circumference equal to 0.6 of the outside diameter of the pipe rests on undisturbed soil.

Bell holes shall be excavated accurately to size by hand.

In rock, excavations shall be carried 8 in. below bottom of pipe. Loose earth or gravel shall be used for backfill and tamped thoroughly.

Rock Excavation shall include removal of boulders larger than $\frac{1}{3}$ cu. yd. in volume and of ledge rock, concrete, or masonry structures that require drilling or blasting.

Bracing and Shoring. The contractor shall do all bracing, sheathing, and shoring necessary to perform and protect all excavations as indicated on the plans, as required for safety, as directed by the engineer, or to conform to governing laws.

Specify that bracing and shoring are to be or *are not to be paid for extra.*

Temporary Bridges or crossings shall be built by the contractor where required to maintain traffic.

IV. Tests.

Tests for workmanship on utility lines shall be conducted in accordance with the applicable utility specification before backfilling.

V. Backfilling.

After pipes have been tested and approved, backfilling shall be done with approved material free from large clods or stones.

Trenches. Backfill material shall be placed evenly and carefully around and over pipe in 6-in. maximum layers. Each layer shall be thoroughly and carefully rammed until 1 ft. of cover exists over pipe.

The remainder of backfill material shall be placed, moistened, and compacted.

Water settling will not be permitted in clay soils. It may be required at the option of the engineer in sandy soils.

Trench under Roadway and Areas to Be Paved. Material shall be placed in 8-in. maximum layers after filling 1 ft. above pipe as previously described. Each layer shall be compacted to density equal to that of adjacent original material so that pavement can be placed immediately.

Manholes and Other Structures. All forms, trash, and debris shall be removed and cleared away. Approved backfill material may be from excavation or borrow; it shall be free from rock, lumber, or debris. Backfill material shall be placed symmetrically on all sides in 8-in. maximum layers. Each layer shall be moistened and compacted with mechanical or hand tampers.

In roadway or area to be paved, each layer shall be compacted to density equal to that of adjacent original material so that pavement can be placed immediately.

Pipes and Culverts in Fill Section or Projecting into Fill Section. Foundation support shall be as shown on the plans. Where pipe is not structurally supported, unstable material shall be removed. A pipe bed and embankment, if required, shall be constructed of selected material and compacted. Selected material shall be placed symmetrically on each side of pipe in 6-in. maximum layers.

Material shall be compacted thoroughly.

Layers shall be placed and compacted until a berm is formed at least one pipe diameter on each side of pipe and 12 in. minimum fill over pipe.

Maintenance. The contractor shall refill for settlement all backfilled areas.

VI. Replacing Pavements.

Subgrades shall be compacted with a mechanical tamper.

The minimum width of replaced concrete pavements shall be 4 ft. at interiors and 6 ft. at joints. *(Avoid cutting pavements at joints; if unavoidable, reconstruct same as original joint.) Depth shall be 1.3 times original thickness. Existing pavement edges shall be cut vertical. (Use 1 : 2 : 3 mix, water-cement ratio 5 gal.; use high-early-strength cement if road is to be opened in less than 3 days.)*

The minimum width of replaced bituminous pavements shall be 3 ft. with base of same depth as original pavements; surface course shall be cold-patch mixture. The existing pavement shall be cut vertically and horizontally to a straight line. Edge of existing pavement shall be painted with RC-3 or RC-4. The patch shall be rolled in both directions with a 5-ton roller.

VII. Clean-up.

The contractor shall clean up and dispose of all excess material, trash, wood forms, and other debris.

VIII. Basis of Payment.

Specify that the contractor be paid at unit or lump sum price called for in the contract.

Give work included and/or excluded under this price.

Give method of measurement.

If unit price, itemize price units.

If lump sum, itemize basis of payment for extra work including the following items:

Price per F.B.M. for sheathing, shoring, and bracing, installed and removed.

Price per F.B.M. for sheathing, shoring, and bracing, installed and not removed.

Price per day for pumping.

Price per cubic yard for rock excavation.

Price per cubic yard for removal of soft material and replacing with gravel.

Price per square yard for replacing pavement.

PAINTING FOR WATER AND SEWAGE-TREATMENT PLANTS

I. Scope of Work.

This work shall include furnishing materials, painting, and preserving the following:

II. Painting.

Painting shall be as per following schedule. *See "Suggestions for Specifying Paints," p. 80.*

Purpose	Number of Coats	General Type	Formula *or* Suggested Manufacturer's Brands

Preparation of Surfaces. The contractor shall provide a proper surface, that is, dry and free from rust, scale, dirt, grease, or other interfering materials. No paint shall be applied on a wet, rusted, or dirty surface. Old paint surfaces shall be sanded, and rusted metal surfaces shall be wire brushed, to secure a suitable surface for a finish coat.

For outside protective work, the combined film thickness of three coats of paint specified shall be not less than 0.006 in.

Paint shall be delivered in original unopened containers bearing manufacturer's labels and shall be used as recommended by the manufacturer without being extended or modified except as directed or approved.

III. Timber Exposed to Sewage.

Timber exposed to sewage shall be treated with creosote. *See applicable portions of specification for "Wood Preservation and Painting, Exposed Structures," p. 67.*

IV. Colors. (*Suggested by Author.*)

Sewage-Treatment Plants

Raw sewage	Green
Purified sewage	Blue
Sludge	Yellow
Mixture of sludge and sewage	Yellow with green bands
Gas	Red
Heating	Silver or aluminum
Water supply	Blue with white stripes
Plumbing drains	Brown
Electrical conduits	Black
Compressed air	Gray
Chlorine	Cream

Water-Purification Plants

Raw or settled water	Green
Filter effluent	Blue
Wash water drain	Yellow
Wash water supply	Blue with yellow bands
Compressed air	Gray
Chemical feed lines	Orange with stripes
Water lines	Blue with white stripes
Heating	Silver or aluminum
Plumbing drains	Brown
Chlorine	Cream

V. Basis of Payment.

Specify that the contractor be paid at unit or lump sum price called for in the contract.

DRAINAGE

DRAINAGE PIPES, GUTTERS, AND DITCHES

I. Scope of Work.

II. Excavation, Trenching, and Backfilling.

Excavation, trenching, and backfilling shall conform to the applicable portions of specifications for "Excavation, Trenching, and Backfilling for Utility Systems," p. 153.

III. Materials.

All pipe installed shall be of the type and class indicated on the drawings.

Culvert Pipe. Vitrified clay pipe, standard and extra strength, shall conform to the latest A.A.S.H.O. Spec. M-65.

Non-reinforced-concrete pipe shall conform to latest A.S.T.M. Spec. C-14.

Reinforced-concrete pipe shall conform to latest A.S.T.M. Spec. C-76.

Elliptically reinforced and elliptical pipe with circular reinforcing shall be clearly marked to indicate correct position of installation. In addition, each section shall be manufactured with a lug or other positive interlocking device.

Corrugated galvanized-metal pipe shall conform to latest A.A.S.H.O. Spec. M-36.

Bituminous coating, where required by the plans, shall consist of asphalt cement having a minimum thickness of 0.04 in. measured at the crest of the corrugations. Immediately before application of the bituminous coating, the pipe shall be cleaned of moisture, dirt, grease, scale, and loose rust. The asphalt cement shall be not less than 99.5% soluble in carbon disulfide. *Use paving for high-velocity flow carrying abrasive materials.*

Paved invert in corrugated pipe, where required by the plans, shall consist of asphalt cement applied on the inside of the pipe for $\frac{1}{4}$ of its circumference (bottom of pipe when installed). The pavement shall have a minimum thickness of 0.50 in. measured on the crest of the corrugations at the center line and shall taper to 0.1 in. at the sides.

Cast-Iron Pipe shall conform to applicable portions of specifications for "Sewer Pipes."

Drain Tile. Farm, standard, and extra-quality drain tile shall conform to latest A.S.T.M. Spec. C-4. Pipe of porous, perforated, or other design intended for subdrainage shall be subject to approval by the engineer.

IV. Installation.

Bedding of the pipe shall conform to the detail shown on the plans. *See p. 5-22, "Data Book—Design."* The bedding surface shall provide a firm foundation, carefully shaped true to line and grade. Bed for bells shall be hollowed out.

Concrete and Vitrified Clay Pipe Culverts shall be laid carefully with hubs upgrade and ends fully and closely jointed. Joints shall be hot-poured bituminous compounds, precast bituminous compound, or cement mortar, and

shall conform to the applicable portions of the specifications for "Sewer Pipes." Bituminous joints shall be used where settlement may occur.

Corrugated Metal Pipe shall be laid with the separate sections firmly joined together.

Joints shall be made by riveting or by means of connecting bands with bolted couplings in accordance with the recommendations of the pipe manufacturer.

When the pipe laps at circumferential joints, the inner lap shall be on the downstream end of the culvert.

Longitudinal laps shall be located at the horizontal axis.

Bituminous paved corrugated metal pipe shall be installed so that the center line of the asphalt pavement coincides with the specified alignment of the pipe. Connection band bolts and damage to coating on the connecting bands and pipe shall be given a coating of asphalt cement. Pipe on which the asphalt coating has been damaged to such an extent that satisfactory field repairs cannot be made, as determined by the engineer, will be rejected.

Pipes 42 in. or larger in diameter shall be elongated vertically 5% by field strutting or by an approved shop method. The struts shall be placed before the backfill is started and shall be removed as directed by the engineer.

Pipe Subdrains. Bell and spigot pipe shall be laid with the bell ends upgrade and in accordance with detail for open joint drains shown on plans.

After pipe subdrains have been laid and have been inspected and approved by the engineer, filter materials of the type and to the depths shown on the plans shall be placed around and over the pipe. Filter materials shall be clean, durable gravel or crushed stone uniformly graded from $\frac{1}{4}$ to $\frac{3}{4}$ in. in size.

Blind or French Drains. After trenches have been excavated to the cross sections and depths shown on the plans, filter material of stones, broken stone, or gravel of the sizes shown on the plans shall be placed to within 12 in. of the finished ground surface.

Or specify filter material for important work. Filter material shall be graded in accordance with instructions given on p. 3-18 of "Data Book—Design."

V. Hand-Laid Riprap.

Hand-laid riprap shall be used for bank protection and placed where shown on the plans.

Material shall be hard, sound, angular quarry stones weighing from 20 to 400 lb. each, of which at least 60% shall weigh more than 100 lb.

The stones shall be placed with their beds at right angles to the slope, the larger stones being used in the bottom courses and the smaller stones at the top. They shall be laid in close contact so as to break joints, and in such manner that the weight of the stone is carried by the earth and not by adjacent stones. The spaces between the larger stones shall be filled with spalls securely rammed into place. The finished work shall present an even, tight, and reasonably smooth surface conforming to the required contour.

VI. Gutters and Ditches.

Specify one or more of the following as called for in the plans.

Cobbled Gutters and Ditches shall be constructed of approved hard, sound, durable quarry or field stones at least 9 in. long, set on edge.

A gravel bed at least 3 in. in depth shall be placed and compacted. The stones shall then be set in position and thoroughly rammed to produce a uniform surface.

Or **Grouted Rubble Gutters and Ditches** shall be constructed of approved hard, sound, durable stones with approximately flat top surfaces. The size of stones shall be as follows:

Thickness	6 to 8 in.
Width	2 in. minimum
Length	6. in minimum

The bed shall be formed at required grade. Soft or unstable material shall be removed and replaced with approved material. The bed shall be thoroughly compacted and finished to a smooth, firm surface.

Where shown on the plans, a layer of cinders, clean sand and gravel, or other approved porous material shall be placed and compacted to form a bed 6 in. thick.

Stones shall be placed in close contact with flat surface up and longest dimension at right angles to the center line of the gutter or ditch.

Each stone shall be thoroughly rammed until the surface is firm and uniform.

There shall be no joints wider than 1 in.

After the surface has been inspected and approved, the joints shall be filled to within 4 in. of the surface with slag, sand, gravel, or crushed stone all of which will pass a $\frac{3}{8}$-in. sieve.

Mortar shall be poured and broomed into the joints until it is flush with the surface of the stones. Mortar shall consist of 1 part cement to 2 parts sand.

Concrete Gutters and Ditches shall be constructed as shown on the plans and in accordance with the applicable portions of the specifications for "Portland Cement Concrete Pavement."

Earth Gutters and Ditches shall be constructed as shown on the plans and in accordance with the applicable portions of the specifications for "Grading for Roads, Airports, and Railroads."

VII. Tests.

Laboratory or Plant Tests. Pipe shall be tested for conformity with the latest revision of the following tests.

		Number of Tests
Concrete pipe	A.S.T.M. C-14	Manufacturer or seller shall furnish specimens equal to 0.5% of order but not less than 2 specimens of each size and type.
Reinforced-concrete pipe	A.S.T.M. C-75	
Reinforced-concrete culvert pipe	A.S.T.M. C-76	
Clay pipe	A.S.T.M. C-13	
Vitrified clay culvert pipe	A.A.S.H.O. M-65	
Drain tile	A.S.T.M. C-4	
Filter material	*See "Data Book—Design," p. 3-18.*	One for each soil type.
Corrugated metal pipe	A.A.S.H.O. M-36	As owner may require.

I. Scope of Work.

II. Concrete Work.

Concrete work shall conform to the applicable portions of specifications for "Structural Concrete."

III. Inlets, Catch Basins, and Manholes.

Excavation shall conform to the applicable portions of specifications for "Excavation, Trenching, and Backfilling for Utility Systems." Foundations shall be constructed of concrete, and the walls shall be constructed as specified on the plans. Where material is not specified, brick, concrete, or concrete rings or block may be used.

Brick shall conform to A.S.T.M. Spec. C-32-42, Grade MA. Mortar for brickwork shall consist of 1 part Portland cement to 2 parts sand, with approximately 20 lb. of hydrated lime.

Portland cement shall conform to A.S.T.M. Designation C-150-42, Type I or II.

Specify Type I or II; when resistance to moderate sulfate action is required, such as exposure to sewage or salt water, specify Type II. Sand shall conform to tentative specification A.S.T.M. C-144-42T. Hydrated lime shall conform to A.S.T.M. Spec. C-6-31.

Brick shall be clean and thoroughly wetted before laying. All joints shall be completely filled and struck to a smooth finish. The outside of brick and precast concrete block structures shall be plastered and troweled smooth with $\frac{1}{2}$ in. of mortar composed of 1 part Portland cement to 2 parts sand. The inside shall be plastered in like manner where so indicated on the plans.

Precast concrete blocks of proper radius shall conform to A.S.T.M. Designation C-139-39. Mortar for laying shall consist of 1 part Portland cement to 2 parts sand. The joints shall be so made as to produce a smooth and uniform surface.

IV. Frames, Covers, Gratings, and Steps.

Frames, covers, and gratings shall be of the type and duty shown on the plans. Iron castings shall conform to the Standard Specifications for Gray Iron Castings, A.S.T.M. Spec. A-48-41, Class 20, *or* 40 (*for airports*).

All castings shall be true to pattern in form and dimensions, free from faults, sponginess, cracks, blowholes, and other defects affecting their strength.

The gratings and covers shall have a minimum section modulus equal to ____; *see those called for in "Data Book —Design," p. 5-19.*

Bearing surfaces between cast frames, covers, and grates shall be machined, fitted together, and match marked to prevent rocking.

Standard galvanized wrought-iron or cast-iron steps shall be installed as indicated on the plans.

V. Maintenance.

All structures shall be maintained in good working order until final acceptance.

VI. Approval of Materials.

Manufacturer's Certificate. (*Omit if laboratory tests are required.*) Materials may be used if accompanied by manufacturer's certificate of compliance, pending any tests which may be made by the engineer.

VII. Tests.

Laboratory or Plant Tests	Number of Tests
Cement	As required by A.S.T.M. C-77-40
Sand	As required by A.S.T.M. C-144-42T
Lime	As required by A.S.T.M. C-110
Precast concrete segments or blocks	As required by A.S.T.M. C-140
Iron castings	As required by A.S.T.M. E-30-42

SEWERS

OUTLINE FOR A COMPLETE SEWERAGE WORKS SPECIFICATION

I. Items to Include.

Title page.

Table of contents.

Invitation to bidders, *see p. 1.*

Proposal forms, *see pp. 4 and 7.*

Contract forms, *see pp. 10 and 13.*

Performance bond.

General conditions, *see p. 18.*

Special conditions, see below.

Detail specifications.

Preparation of site, *see p. 29.*

Excavation and grading for structures, *see p. 31.*

Drainage pipes and gutters, *see p. 157.*

Drainage structure, *see p. 160.*

Sewer pipes, *see p. 163.*

Sewer structures, *see p. 167.*

Equipment for sewage-treatment plant, *see pp. 171 to 184 incl.*

Structural, *see pp. 30 to 86 incl.*

Pumps, *see p. 182.*

Painting, *see p. 156.*

Buildings as required.

Water distribution, *see p. 197.*

Roads, *see pp. 87 to 134 incl.*

Electrical as required.

Plumbing as required.

Heating and ventilating as required.

II. Special Conditions. *See also p. 26.*

Services of Manufacturer's Engineer. During the first year of operation, the supplier of the following equipment shall furnish the services of a competent representative for the number of days and trips listed below.

	Man-Days	Trips
Bar screen	6	3
Grinders or comminutors	4	2
Mechanically cleaned sedimentation tanks	15	5
Filters with fixed nozzles	6	3
Filters with rotary distributors	15	5
Diffusers of mechanical aerators for actuated sludge plants	15	5
Dosing siphons	1	1
Pumps	1	1
Digestion equipment	15	5
Chlorinators	4	2
Hypochlorinator	1	1

Specify additional as required.

The purpose of this service is to instruct the plant-operating personnel in the maintenance and care of the equipment and to conduct tests and make recommendations for producing the most efficient results. A report shall be submitted to the chief operator or superintendent and the engineer by the manufacturer after each visit, stating the operating conditions and results of the tests, and offering suggestions and recommendations for improvements in operation. The actual dates when such services are to be given will be arranged with the manufacturer by the superintendent or the engineer, but the first trip shall be made during the initial operation of the completed plant. The price bid for the equipment shall include the complete cost of services specified above.

III. Guarantees.

Upon completion of the work and before the release of retained percentages, the contractor shall furnish a bond or bonds covering the following items of work for the periods stated as a guarantee of satisfactory operation of the equipment and the correction of any defects in the work, material, or equipment furnished by him.

Description	Amount of Bond	Period
Waterproofing	$____	2 years
All mechanical equipment	$____	1 year
Piping	$____	1 year
Roofing	$____	3 years
Other items	$____	____

IV. Delimitation of Work.

Service contractors (electrical, heating, plumbing, etc.) will make all connections to equipment and will mount and test all controls. Manufacturers will furnish all controls with equipment unless otherwise specified. (*"Scope of Work" clauses in electrical, plumbing, heating and ventilating, etc., and similar clauses in equipment specifications should be written so that there will be neither overlapping nor omission of any work.*)

Note: specify additional clauses as required.

SEWER PIPES

I. Scope of Work.

II. Excavation, Trenching, and Backfilling.

All excavation, trenching, and backfilling shall conform to applicable portions of specifications for "Excavation, Trenching, and Backfilling for Utility Systems."

III. Pipe.

All pipe shall conform to the sizes and materials shown on the plan.

Pipe shall be in accordance with the following:

Vitrified clay pipe and fittings, A.S.T.M. Spec. C-13.

If glazed, the inside of the bell and outside of the spigot shall be scored in three parallel lines extending completely around the circumference.

Concrete sewer pipe and fittings, A.S.T.M. Spec. C-14.

Reinforced-concrete sewer pipe and fittings, A.S.T.M. Spec. C-75.

All concrete pipe shall be bell and spigot except that tongue and groove may be used for sizes over 21 in.

Cement-asbestos pipe shall be that manufactured by Johns-Manville Corporation, Keasbey & Mattison Co., or approved equal.

Specials for cement-asbestos pipe shall be cast iron.

Cast-iron pipe and specials shall conform to Fed. Spec. WW-P-421 for class shown on plans, or A.S.A. Spec. A21.2, latest edition, of equivalent strength.

All cast-iron sewer pipe shall be painted as follows: *See "Suggestions for Specifying Paints," p. 84.*

IV. Joints.

All joints shall conform with the following table:

	Type of Joint						
Pipe	*Hot-Poured Bituminous Compound*	*Precast Bituminous Compound*	*Cement Mortar*	*Lead*	*Mechanical*	*Bolted*	*As Recommended by Manufacturer*
Clay	x	x	x				
Concrete	x	x	x				
Cement-asbestos							x †
Cast-iron	x		x	x *	x *	x *	

* Where shown on plans.

† Johns-Manville Corporation, Keasbey & Mattison Co., or approved equal.

Hot-Poured Bituminous Compound shall be GK Compound, Jointite, or approved equal.

Precast Bituminous Compound shall be Slip Seal, Slip Joint, Servicised, or approved equal.

Cement Mortar shall consist of 1 part Portland cement and $1\frac{1}{2}$ parts clean sharp sand with only enough water for workability.

Lead Joints shall be of best-quality soft pig lead suitable for calking and securing tight permanent joints.

Mechanical Joints shall be of the stuffing-box type adapted for use of a gasket, cast-iron gland, and bolts. Joint parts shall be Doublex Simplex Joint, U. S. Joint, Boltite Joint, or approved equal.

Bolted Joints shall consist of bolts, nuts, and washers of a type and size recommended by the pipe manufacturer.

V. Laying Pipe.

All sewers shall be laid true to line and grade with bells upgrade. The sections of the pipe shall be so laid and fitted together that, when complete, the sewer will have a smooth and uniform invert. The pipe shall be kept thoroughly clean so that jointing compounds will adhere. Each pipe shall be inspected for defects before being lowered into the trench.

Water in Trenches. Water shall not be allowed in the trenches while the pipes are being laid. Water shall not be allowed to rise around the joint until it has set.

Limit of Trench Opened. Not more than 100 ft. of trench shall be opened in advance of pipe laying unless permitted by the engineer.

Exposed Ends Protected. The excavation of trenches shall be fully completed a sufficient distance in advance of the laying of the sewer, and the exposed end of all pipes shall be fully protected with a board or other approved stopper to prevent earth or other substances from entering the pipe.

Pipes Kept Clean. The interior of the sewer shall be carefully freed from all dirt, cement, or superfluous material of every description as the work progresses.

VI. Jointing Pipe.

Approved bituminous joint materials shall be handled, heated, and poured in accordance with the recommendations of the manufacturer. All joints shall be wiped smooth inside the pipe.

Hot-Poured Bituminous Compound Joints. A gasket of closely twisted hemp or oakum shall be placed around the pipe. The gasket shall be in one piece of suitable diameter (not less than $\frac{3}{4}$ in.) and shall be lapped at the top. The gasket shall be rammed solidly and tightly home into the annular space within the socket of the pipe with a suitable calking tool. A suitable runner shall be placed around the pipe to close the socket opening. The bituminous compound shall be heated to approximately 350° F. Compound shall be poured into the joint in such a manner that the annular space will be completely filled.

Precast Bituminous Compound Joints. Before a joint is made, each collar shall be brushed with a solvent recommended by the manufacturer of the joint material, which will cause the surface to become plastic or adhesive. All collars will be inspected before being laid and any showing voids or injury will be rejected.

Cement Mortar Joints. The same type of gasket shall be used as specified above for "Hot-Poured Bituminous Compound Joints." The gasket shall be saturated with neat cement before being placed and rammed. The joint shall be completely filled with cement mortar and rammed thoroughly with a wooden calking tool. The joint shall then be overfilled and finished to a smooth bevel outside. On tongue-and-groove pipe the joint shall be pointed up with mortar, and a band or bead shall be formed to cover the joint on the outside of the pipe as shown on the plans.

Cement-Asbestos Pipe Joints shall be made in accordance with the recommendations of the pipe manufacturer when approved by the engineer.

Lead Joints. The same type of gasket shall be used (except with $\frac{1}{2}$ in. minimum diameter). It shall be placed and rammed as specified above for "Hot-Poured Bituminous Compound Joints." The lead shall be heated to a temperature such that when stirred it will show a rapid change in color. Scum shall be removed before pouring.

A runner shall be placed around the pipe and against the face of the bell. Lead shall be poured to fill the joint completely. Calking shall be done with a suitable calking tool.

Mechanical Joints shall be made in accordance with the recommendations of the joint manufacturer.

Bolted Joints shall be made in accordance with the recommendations of the bolted-pipe manufacturer.

VII. Connections.

All connections which are for future use shall be properly capped.

No pipe shall be cut for connections except when permitted by the engineer.

Service Connections. Wyes for service connections shall be installed where shown on the plans.

Pipes Cut to Fit Masonry. The ends of pipe which enter masonry shall be neatly cut to fit the inner face of the masonry. When directed, such cutting shall be done before the pipes are built in.

VIII. Inspection of Joints.

Joints shall not be covered until approved by the engineer.

IX. Approval of Materials.

Manufacturer's Certificate. *Omit if laboratory tests are required.* Materials may be used if accompanied by manufacturer's certificate of compliance, pending any tests which may be made by the engineer.

Bituminous Joint Materials shall be delivered on the job in the manufacturer's container clearly marked and unopened.

X. Tests.

Laboratory or Plant Tests. Pipe shall be tested for conformity with the latest revision of the following tests.

		Number of Tests
Vitrified clay pipe	A.S.T.M. C-13	Manufacturer or seller shall furnish specimens equal to 0.5% of order but not less than 2 specimens of each size and type.
Concrete pipe	A.S.T.M. C-14	
Reinforced-concrete pipe	A.S.T.M. C-75	

Specify tests to be made as follows: At manufacturing plant in the presence of the engineer or at a commercial laboratory designated by the engineer.

Specify manufacturer or contractor or owner to pay for testing.

Cement-asbestos pipe	Johns-Manville or Keasbey & Mattison Co. or equal specification.	As required by manufacturer's specification.
Cast-iron pipe	Fed. Spec. WW-P-421 or A.S.A.	As required by specifications for size and class of pipe.

Field Tests.

Alignment. After joints have been inspected and approved, backfill to 1 ft. above pipe as specified in "Excavation, Trenching, and Backfilling for Utility Systems"; flash a light between manholes or manhole locations. If alignment is true and no pipes are misplaced, backfilling may be continued. Test until satisfactory.

Infiltration. Tests for watertightness shall be made by the contractor in the presence of the engineer, and the sewer and connections shall not leak under the exterior normal ground-water pressure in excess of a rate of 10,000 U. S. gal. per mile of sewer for 24 hr. The tests and the measurement of infiltration shall be conducted in a manner as approved by the engineer. Test until satisfactory.

Inspection of pipe for thickness, straightness, soundness, and cracks: test each piece. *See "Data Book—Design," pp. 5-20 and 5-21 for pipe thickness.*

Inspection of bituminous joint materials and containers: test each container.

XI. Basis of Payment.

Specify that the contractor be paid at unit or lump sum price called for in the contract.

Give work included and/or excluded under this price.

Give method of measurement.

If unit price, itemize price units. Call for bid prices on substitutes thought desirable.

If lump sum, itemize basis of payment for extra work, including the following item: price per linear foot for (size), (type) pipe complete in place.

SEWER STRUCTURES

I. Scope of Work.

II. Concrete Work.

Concrete work shall conform to the plans and to the applicable portions of the specifications for "Structural Concrete."

III. Concrete Cradles.

Where called for on the plans, concrete cradles shall be constructed for the full width of the cradle to within 2 in. of the bottom of the pipe. The pipe shall then be set to line and grade on wedges and the remainder of the cradle shall be placed.

IV. Manholes.

Manholes shall be constructed of brick, concrete, or precast concrete blocks, with cast-iron frames and covers as shown on the plans.

Manholes shall be constructed only when temperature is above 32° F. All work shall be protected against freezing.

Invert channels shall be smooth, accurately shaped, and in accordance with the plans.

Invert may be formed directly in the concrete of the manhole base; be built up of brickwork and mortar; consist of half tile laid in the concrete base; or be constructed by laying full section sewer pipe straight through the manhole and cutting out the top half after the concrete base is constructed and sufficiently set.

Cast-iron or galvanized wrought-iron steps shall be installed as shown on the plans.

Cast iron shall conform to A.S.T.M. Spec. A-48.

Wrought iron shall conform to A.S.T.M. Spec. A-41.

The rungs shall have a minimum length of 10 in. and be at least $\frac{3}{4}$ in. in diameter.

Manholes shall be built up so that the cover when placed will be at the required grade.

Brick shall conform to the A.S.T.M. Spec. C-32, Grade MA.

Mortar for laying bricks shall be composed of 1 part cement to 2 parts sand, with approximately 20 lb. hydrated lime added for each sack.

Cement, sand, and hydrated lime shall conform to the applicable portions of specification for "Masonry."

Bricks shall be clean and thoroughly wetted shortly before they are laid. They shall be laid in a full bed and joint of mortar and shall be shoved in place so that all joints are completely filled.

The outside of brick and precast concrete block manholes shall be plastered and troweled smooth with $\frac{1}{2}$ in. of mortar composed of 1 part cement to 2 parts sand. The inside shall be plastered in like manner where so indicated on the plans.

Precast concrete blocks of proper radius shall conform to A.S.T.M. Spec. C-139.

Precast concrete blocks shall be laid up with mortar composed of 1 part cement to 2 parts sand, in a manner that will insure watertight joints. The joints shall be made so as to produce a smooth and regular surface.

V. Frames, Covers, and Gratings.

Frames, covers, and gratings shall be of the type and duty shown on the plans. Iron castings shall conform to the Standard Specifications for Gray Iron Castings, A.S.T.M. Spec. A-48-41, Class 20.

All castings shall be true to pattern in form and dimensions, free from faults, sponginess, cracks, blowholes, and other defects affecting their strength.

The gratings and covers shall have a minimum section modulus equal to ____; *see those called for in "Data Book—Design," p. 5-19;* 3,000 working stress equal to Class 20.

Bearing surfaces between cast frames, covers, and grates shall be machined, fitted together, and match-marked to prevent rocking.

Standard galvanized wrought-iron or cast-iron steps shall be installed as indicated on the plans.

VI. Receiving Basins, Settling Basins, and Inlets.

Receiving basins, settling basins, and inlets shall be of brick, concrete, or concrete block, as called for on the plans. Materials shall conform to the applicable requirements for manholes in paragraphs IV and V above.

Brick or concrete block structures shall be plastered inside and outside with $\frac{1}{2}$ in. of cement mortar composed of 1 part cement to 2 parts sand.

Where built of concrete, the side walls and bottom between expansion joints shall be constructed in one continuous pour. Concrete receiving basins and settling basins shall be coated on the inside with neat cement grout.

VII. Maintenance.

All sewer structures shall be thoroughly cleaned and maintained in workable condition until final acceptance.

VIII. Approval of Materials.

Manufacturer's Certificate. *Omit if laboratory tests are required.* Materials may be used if accompanied by manufacturer's certificate of compliance, pending any tests which may be made by the engineer.

IX. Tests.

Laboratory or Plant Tests.

		Number of Tests
Brick	A.S.T.M. C-67	As required by A.S.T.M. C-67 for brick and A.S.T.M. C-140 for concrete block.
Precast concrete block	A.S.T.M. C-140	

Specify tests to be made as follows: At manufacturing plant in the presence of the engineer or at a commerical laboratory designated by the engineer.

Specify manufacturer or contractor or owner to pay for testing.

Cast-iron frames, covers, grates or steps	A.S.T.M. A-48	Manufacturer shall perform tests and submit certificate for conformity with the specification.
Wrought-iron steps	A.S.T.M. A-41	

Field Tests.

Inspection of brick for breakage, size, and appearance: test each shipment.

Inspection of concrete block for size and shape: the engineer may require the contractor to furnish and ship at least 10 samples to an independent testing laboratory designated by the engineer. The owner will pay for tests made by an independent laboratory.

Inspection of frames, covers, grates, and steps for size, appearance, trueness, soundness, and cracks: test each piece.

X. Basis of Payment.

Specify that the contractor be paid at unit or lump sum price called for in the contract.

Give work included and/or excluded under this price.

Give method of measurement.

If unit price, itemize price units.

If lump sum, itemize basis of payment for extra work, including the following items:

Price per cubic yard for concrete cradles complete in place.

Price for each type of manhole, complete in place with frame and cover.

Price for each type of receiving basin, settling basin, or inlet complete in place with frame, cover, and/or grates.

SEWAGE TREATMENT

SCREENS MANUALLY CLEANED

(Used in small plants. Frequently installed in bypass channel of large plants for emergency use in case of mechanical failure.)

I. Scope of Work.

This work shall include furnishing, installing, and painting screens and providing rakes.

II. Equipment.

Screen shall be of steel bars installed as shown on plans. ____ rakes with teeth ____ in. long, spaced to fit between screen bars, shall be furnished with ash handles ____ ft. long.

SCREENS MECHANICALLY CLEANED

I. Scope of Work.

This work shall include furnishing, installing, and painting mechanically cleaned bar screens and controls as shown on plans; it shall also include furnishing working and shop drawings, testing, and operation services specified in "General Conditions."

II. Screen and Rake Mechanism and Controls.

The mechanism shall be designed for installation in a channel of width and depth shown on the plans; it shall consist of a bar screen, cleaning device, drive unit, housing, electrical controls, panel board, and anchor bolts.

Screen bars shall be of steel and of size and spacing shown on the plans. The slope of screen, rake mechanism, support housing (*specify partially or completely enclosed*), shafts, bearings, magnetic reversing switch and alarm, limit switch, time switch and clocks, emergency float switch, motor (*specify splashproof if outdoors and not housed*), magnetic starter, and other appurtenances shall be of approved design and suitable for operating with ____ cycle, ____ phase, ____ volt current.

Equipment shall be that manufactured by Chain Belt Co., Link-Belt Co., or approved equal.

SETTLING TANKS (CLARIFIER)

(*Designer should decide on rectangular or circular tanks before writing specification.*)

I. Scope of Work.

This work shall include furnishing, installing, and painting sludge-removal mechanism with skimming device (*skimming device may be omitted at final tanks*), motors, and controls for ____ tanks of dimensions shown on plans; it shall also include furnishing working and shop drawings, testing, and operation services specified in "General Conditions."

II. Sludge-Removal Mechanism.

Sludge-removal mechanism shall be complete with all appurtenances, including center column (*omit for rectangular tanks*), inlet baffles, drive mechanism and supports, access bridge (*omit access bridge for rectangular tanks*), steel effluent weirs, motors and controls, and skimming device with baffle for continuous removing of scum from surface of tanks.

III. Motor and Controls.

The drive units shall be approved motors and reducers of ample size and capacity to operate the mechanism under all conditions. Motors shall be totally enclosed with removable covers and with moistureproof windings and shall be suitable for exposed operation on ____ phase, ____ cycle, ____ volt current.

An approved magnetic starter shall be furnished for motor with overload and undervoltage protection and with start-stop push buttons on the cover. In addition, separate start-stop push-button control, housed in watertight case, shall be provided for mounting near the drive mechanism. An overload relay shall be furnished, arranged to sound an alarm electrically and to stop the motor in the event of excessive load.

For circular tanks: Equipment shall be that manufactured by Dorr Co., Link-Belt Co., or approved equal.

For rectangular tanks: Equipment shall be that manufactured by Link-Belt Co., Chain Belt Co., or approved equal.

INTERMITTENT SAND FILTER, DOSING SIPHONS

I. Scope of Work.

This work shall include furnishing, installing, and painting ____ siphons and necessary piping, starting devices, etc., as shown on plans; it shall also include furnishing working and shop drawings, testing, and operation services specified in "General Conditions."

II. Siphons.

Siphons shall be the ____ in. deep seal single siphon type *or* plural alternating type A *or* plural alternating type B. (*Use single siphon type if only one bed or manual control; use plural alternating for two or more beds to be automatically dosed. For additional information, see "Data Book—Design," p. 5-51.*) Siphons shall operate under a maximum head of ____ ft. ____ in. having an approximate capacity of ____ gal. per min., and minimum head of ____ ft. ____ in. having an approximate capacity of ____ gal. per min.

Siphons shall be made by Pacific Flush Tank Co. or approved equal.

SLUDGE BEDS AND INTERMITTENT SAND FILTERS—SAND, GRAVEL, AND UNDERDRAINS

I. Scope of Work.

This work shall include furnishing and placing graded sand and gravel and tile drains as shown on plans and specified below.

II. Filter Sand.

Sand shall be clean, hard, sharp grains of siliceous material, free from soft or flaky particles, shale, loam, organic matter, or other deleterious substances.

Sand shall pass $\frac{1}{4}$-in. screen; it shall be washed and graded so as to have an effective size ranging between 0.30 and 0.50 mm. and a uniformity coefficient not in excess of 4.0 for sand filters and 5.0 for sludge beds.

Torpedo Sand shall be of size 0.8 to 1.2 mm.

III. Filter Gravel.

(If not available, substitute crushed stone of comparable quality.)

Gravel shall consist of clean, hard, durable rounded rock fragments free from soft, friable, thin, or laminated pieces, loam, and organic or other deleterious substances.

Gravel shall be graded and placed in layers as follows:

Bottom of trench to top of tile drain	Average 1 in., max. $1\frac{1}{2}$ in., min. $\frac{3}{4}$ in.
Top of tile drain to 3 in. below sand layer	1 to $\frac{1}{2}$ in., uniformly graded
Top 3 in. of gravel	$\frac{1}{2}$ to $\frac{1}{4}$ in., uniformly graded

Not more than 5% by volume shall be larger or smaller than the sizes specified.

Gravel shall be placed carefully to avoid damage to tile drain.

IV. Approval of Materials.

Before use, samples of sand and gravel shall be submitted for test, and no material shall be used until approved.

V. Supplier's Certificate.

Sand and gravel may be used if accompanied by supplier's certificate of compliance, pending any tests which may be made by the engineer.

VI. Laboratory, Plant, or Field Tests.

Sand and gravel shall be tested for gradation in accordance with A.S.T.M. Designation C-136-39, and effective size and uniformity coefficient shall be determined. One test shall be made on each sample submitted for approval, and one test shall be made daily on material delivered. *See "Data Book—Field."*

VII. Underdrains.

Underdrains shall be unglazed clay farm drain tile with plain ends conforming to A.S.T.M. Spec. C-4-24; $\frac{1}{4}$ in. clear space shall be left between ends of pipes. Each joint shall be wrapped with muslin, cheesecloth, or burlap. No jointing material shall be used.

TRICKLING FILTERS, STONE AND UNDERDRAINS

I. Scope of Work.

This work shall include furnishing and placing stone and underdrain tile as shown on plans and specified below.

II. Stone.

Stone shall be washed and graded hard, durable fragments of granite, trap, or other approved rock, free from thin or long pieces, screenings, dust, fine stone, and foreign substances.

The stone shall be well graded between:

$1\frac{1}{2}$ in. and 3 in. (standard low-rate filter)
2 in. and $3\frac{1}{2}$ in. (primary filter of high-rate filters)
$1\frac{1}{2}$ in. and $2\frac{1}{2}$ in. (secondary filter of high-rate filters)

Not more than 5% by volume shall be smaller or larger than the limits specified.

Stone shall be placed carefully on the underdrain tiles to prevent underdrains from being damaged and shall be placed so that segregation of fine and coarse material will not take place.

III. Approval of Stone.

Before use, sample of stone shall be submitted for test, and no material shall be used until approved.

IV. Supplier's Certificate.

Stone may be used if accompanied by supplier's certificate of compliance, pending any tests which may be made by the engineer.

V. Underdrain Tile.

Underdrain tile shall be approximately 12 in. by 18 in. by $4\frac{1}{4}$ in. high and have top opening area equal to at least 20% of the top area. Perforated cover plates for the effluent drainage channel, vent cover blocks along the wall of the tank, and 4-in. tile vents with vent caps shall also be furnished and installed as shown on the plans.

Underdrain tile shall have a compressive strength with loads applied in the same direction as in service of at least 500 lb. per sq. in. The average water absorption of the block by 1-hr. submersion in boiling water shall not exceed 5% of the dry weight of the block.

Underdrain tile shall be Armcre as made by Ayer-McCarel-Reagan Clay Co., of Brazil, Indiana; Natco as made by National Fireproof Corporation, Pittsburgh, Pa.; Translot as made by Cannelton Sewer Pipe Co., Cannelton, Indiana; or approved equal.

Underdrain tile shall be laid in longitudinal rows perpendicular to the drainage channel. The blocks in each row shall be laid in true alignment and with cross joints staggered in each row. The filter blocks shall be laid and embedded in a thin layer of cement mortar screeded to a level surface to take up any unevenness in the floor. All filter tile shall be laid in accordance with detail layout drawings which shall be furnished by the manufacturer of the tile and be approved by the engineer before the tile is laid.

VI. Tests.

Laboratory or Plant Tests. Methods of tests shall be the latest revision of the following:

Filter Stone		Number of Tests
Sieve analysis	A.S.T.M. C-136	1 for each shipment.
Sodium sulfate soundness test (Material shall be rejected if 10% of the pieces fail or if the total debris smaller than 0.5 in. exceeds 10% by weight.)	A.S.T.M. C-88	One at start of work and whenever source or appearance changes.

TRICKLING FILTERS, ROTARY DISTRIBUTORS

I. Scope of Work.

This work shall include furnishing, installing, and painting rotary distributors for ___ trickling filters of dimensions shown on plans. It shall also include furnishing working and shop drawings, testing, and operation services specified under "General Conditions."

II. Rotary Distributor Mechanism.

The rotary distributor mechanism shall be designed for a range of flow from ___ million to ___ million gallons per day with a maximum head of ___ ft. measured from the water level in the center column to the top of the stone. It shall be equipped with approved-type center column containing feature for adjustment of vertical alignment and support, mercury seal and drain, ball bearings, drain valve, anchor bolts, overflow ring, two *or* four arms * of wrought iron *or* steel, † galvanized guy rods, shutters, and dump gates for end arms.

Equipment shall be that manufactured by Dorr Co., Link-Belt Co., Pacific Flush Tank Co., or approved equal.

* Four arms are generally used. Two arms may be enough for small installations if it is desired to save expense.

† Wrought iron is more durable and also more expensive than steel.

SCREENINGS GRINDER

(*Used where it is desired to return screenings to sewage.*)

I. Scope of Work.

This work shall include furnishing, installing, and painting screenings grinder and controls; it shall also include furnishing working and shop drawings, testing, and operation services specified under "General Conditions."

II. Grinder.

The mechanism shall have a capacity of at least ____ lb. or ____ cu. ft. of screenings per hr., and shall consist of grinder, ____ hp., splashproof motor for ____ phase, ____ cycle, ____ volt current, base, feeder pan, rake, water piping assembly and mountings with hose take-off and valve, electrical control with magnetic starter and push-button control station, and metal housing for entire unit.

The unit shall be a Triturator as manufactured by the Chain Belt Co. or an approved equal.

COMMINUTORS

I. Scope of Work.

This work shall include furnishing, installing, and painting comminutors, motors, and controls, as shown on plans; it shall also include furnishing working and shop drawings, testing, and operation services as specified under "General Conditions."

II. Comminutors.

The comminutors shall be designed to pass an average flow of ____ gallons per day and a maximum hourly flow of ____ gallons. Each comminutor shall be furnished with one complete extra set of cutting teeth and one extra comb. The comminutor shall be driven by a ____ hp. weatherproof motor. Motor shall be wound for ____ volts, ____ phase, ____ wire, and ____ cycle current. Controls shall consist of a motor switch and automatic starter in an enclosed panel, floor *or* wall mounted. (*If controls are outdoor, specify controls to be in weatherproof cabinet.*)

Equipment shall be as manufactured by the Chicago Pump Co.

HYPOCHLORINATOR

(*Used in small plants instead of chlorinator.*)

I. Scope of Work.

This work shall include furnishing and installing hypochlorinator, crock for hypochlorite solution, strainer (*motor and switch, for electrically operated hypochlorinator only*), chlorine-resistant solution pipe line and diffuser and other necessary chlorine valves, piping, hose, painting, and spare parts (*for automatic hypochlorinator*), and also necessary automatic control devices. It shall also include furnishing working and shop drawings, testing, and operation services specified under "General Conditions."

II. Hypochlorinator.

The hypochlorinator shall be manual *or* automatic control, electrically *or* water operated, designed to feed hypochlorite solution to sewage. The hypochlorinator shall have a capacity of 5 lb. of chlorine per 24 hr. when running continuously, using a hypochlorite solution of 1% strength. The hypochlorinator shall be provided with adjustment for dosage as well as for varying the strength of the hypochlorite solution.

Equipment shall be that manufactured by Wallace & Tiernan Co., Proportioneers, Inc., or approved equal.

CHLORINATOR

I. Scope of Work.

This work shall include furnishing and installing manual *or* automatic chlorinator complete with all accessories and piping, including the following: extra heavy black wrought-iron chlorine gas header, chlorine-pressure-reducing valve, water-pressure-regulating valve, chlorine resistant solution line and diffuser, chlorine meters, chlorine valves, header valves, manifold and pipe hanger supports, flexible copper tubing connections, platform scale, and all piping hose, conduits, appurtenances, and painting. (*The following sentence applies only to automatic chlorinators.*) It shall also include furnishing and installing equalizing pipe from float well to weir *or* Parshall flume, float well and float, and float-operated converter with necessary piping and accessories to chlorinator.

The work shall also include furnishing ___ duplicate spare parts of all glassware, one testing outfit for chlorine residual, and ___ gas masks, each with extra canister. It shall also include furnishing working and shop drawings, testing, and operating services as specified under "General Conditions."

II. Chlorinator.

The chlorinator shall be ___ lb. per 24 hr. solution feed, visible vacuum-type chlorinator, manual *or* automatic type, as manufactured by Wallace & Tiernan Co. or approved equal. ___ meters, accurate within 4%, shall be furnished to control flow between a minimum rate of ___ lb. per 24 hr. and a maximum rate of ___ lb. per 24 hr. (*The following applies only to automatic chlorinators.*) The automatic chlorinator shall be so designed as to permit manual operation.

III. Platform Scale.

The platform scale shall be of ___ lb. capacity with: (*small installations, under 1500 lb.*) portable platform approximately ___ by ___ in., equipped with standard beam; (*large installations, over 1500 lb.*) skeleton frame, coping angles, etc., for recessing scale in floor. The scale shall be dial indicating with platform approximately ___ by ___ in. The dial shall be graduated to ___ lb. (*weight of chlorine gas exclusive of cylinders*), and the additional weight on the scale shall be carried by the tare and capacity beam.

The scale shall be that made by Fairbanks-Morse & Co., Howe Scale Co., Toledo Scale Co., or approved equal.

IV. Testing Outfit.

The testing outfit shall include one chlorine comparator, complete with color disk, prismatic eyepiece, ten 25-mm. test tubes, and 100 cc. of orthotolidine solution. The testing outfit shall have a range for residual chlorine from 0.1 to 10 p.p.m. It shall be that made by Wallace & Teirnan or approved equal.

SEWAGE PUMPS

I. Scope of Work.

This work shall include furnishing, installing, and painting pump, motor, and gasoline standby (*standby may or may not be used*), shafting and flexible couplings, base plate, anchor bolts, and all electrical and float control equipment as shown on plans; it shall also include furnishing working and shop drawings, testing, and operation services as specified under "General Conditions."

II. Centrifugal and Propeller Pumps. *(Fill in blanks from design.)*

Item and Number	Type	Operating Conditions	Suction (S.) Discharge (D.) Passable Solid (P.S.) *	Manufacturer	Remarks
Raw sewage pump No. __	Heavy-duty vertical *or* horizontal Dry pit *or* wet pit, non-clog Centrifugal	Total ___ g.p.m. against dynamic head of ___ ft. with speed of ___ r.p.m.	__ in. (S.) __ in. (D.) __ in. (P.S.)	Chicago Pump Co. Fairbanks-Morse Co. Gardner-Denver Co. or approved equal	*Vertical dry-pit type generally used; 500 to 1200 r.p.m. is specified.*
Recirculating pump No. __	Vertical propeller type with high efficiency when pumping large volumes against small heads	Total ___ g.p.m. against dynamic head of ___ ft. with speed of ___ r.p.m.	__ in. (S.) __ in. (D.)	American Well Works Fairbanks-Morse Co. Peerless Pump Co. or approved equal	*Used for returning settled and filtered sewage as in biofiltration process suitable for large volumes (500 to 40,000 g.p.m.) pumped against small heads (6 to 15 ft.).*
Sludge pump for final settling-tank sludge No. __	Heavy-duty vertical *or* horizontal Dry pit *or* wet pit, non-clog Centrifugal	Total ___ g.p.m. against dynamic head of ___ ft. with speed of ___ r.p.m.	__ in. (S.) __ in. (D.) __ in. (P.S.)	Chicago Pump Co. Fairbanks-Morse Co. Gardner-Denver Co. or approved equal	*Used for sludge in tanks following rock filters in biofiltration or aeration tanks in activated-sludge process. Horizontal dry-pit type generally used.*
Hot water circulating pump No. __	Centrifugal; suitable for water at __° C.	Total ___ g.p.m. against dynamic head of ___ ft. with speed of ___ r.p.m.	__ in. (S.) __ in. (D.)	Chicago Pump Co. Fairbanks-Morse Co. Gardner-Denver Co. or approved equal	*For digester or other heating systems. For digester heating system 105° C. is generally specified.*

* The impeller and volute shall be large enough to pass solids of the following diameters: 4 in. suction, 2½-in. diameter; 6-in. suction, 4-in. diameter; 8 in. suction and over, 6-in. diameter.

The volute (*centrifugal type*) *or* pump bowl (*propeller type*) shall be made of dense close-grained cast iron. The impeller (*centrifugal type*) *or* propeller (*propeller type*) shall be made of bronze. The shaft shall be made of high-grade manganese steel. Base plate for motor and pump unit shall be made of cast iron *or* steel. Flexible couplings and intermediate bearings of adequate strength and proper design shall be provided for shaft connecting pump and motor.

III. Plunger-Type Pump.

Item and Number	Type	Operating Conditions	Suction (S.) Discharge (D.)	Manufacturer	Remarks
Sludge pump for primary settling tank No. __	Plunger	___ g.p.m. against total dynamic head of ___ ft.	__ in. (S.) __ in. (D.)	Chicago Pump Co. or approved equal	*Simplex (75 max. g.p.m. vs. 40-ft. head)* *Duplex (150 max. g.p.m. vs. 40-ft. head)* *Triplex (225 max. g.p.m. vs. 40-ft. head)*

The plunger-type head shall have adequate air chambers on both suction and discharge, sampling connection on discharge side, revolution counter, vacuum pressure gage on suction side, pressure gage on discharge side, adjustable eccentric release to change the length of stroke, and shear pin overload release.

Drive units shall connect to pipes by means of suitably guarded V-belt drive from drive unit to countershaft and enclosed gear reduction unit from countershaft to main shaft. The gear reduction unit shall be so constructed that the gears shall run in oil.

(*Motor unit may operate at one speed or contain a variable-speed unit. It is generally used on one or more of the pump and motor units, depending on operating conditions.*) A variable-speed transmission of approved make and type shall be combined in a single integral unit with the motor. The variable-speed unit shall have a speed ratio of ____ to 1, micro-speed control, automatic belt tensioner, and ball-bearing construction throughout.

IV. Electric Motors and Controllers.

(*The engineer should check with a local electric company and verify characteristics of current available.*) Motors shall be ____ hp. (*same as pump*), capable of operating satisfactorily with (*if alternating current*) ____ phase, ____ cycle, ____ wires, and ____ volts *or* (*if direct current*) ____ wires and ____ volts. Motors shall be of ____ type (*specify open, weatherproof, ventilating, or explosion proof type as required*), as manufactured by General Electric, Westinghouse, or equal.

Motors shall be designed for 40° C. rise when of the open type and 50° C. rise when of the fully enclosed type and shall be constructed in accordance with the rules of the A.I.E.E. and the National Electrical Code.

Motors are to be wound for the service voltage, and the voltage drop in the power feeders to the motor shall not exceed 5% when the motor is fully loaded.

Starters shall be of ____ type. (*Specify "across the line" or "step starters," as required by local electric company. It is good practice and often required to specify stepped starters for motors over 20 hp. to reduce current inrush and so to protect other service lines from voltage variations.*) All starters shall be protected by a fused main line switch and shall be waterproof or explosion proof, as shown on plans. Across-the-line starters shall be of ____ type (*specify manual or magnetic, as required*), as manufactured by General Electric *or* Westinghouse. Magnetic starters shall be equipped with overload relays and undervoltage and phase protection.

Step starters shall be of the reduced voltage primary resistor type, as manufactured by General Electric *or* Westinghouse, with the number of accelerating steps as required to keep the current increments within the limitations of the local electric company requirements. Where operation of motors cannot be observed from the starter location, a separate non-fusible disconnect switch shall be installed adjacent to the motor.

All remote-operated push buttons called for by the plans shall be equipped with pilot lights to indicate motor operation.

Float switches shall be installed where shown on plans and shall be as manufactured by Cutler-Hammer, Westinghouse, *or* General Electric. (*Specify acidproof if in sewage or other corrosive liquids.*)

Wherever float switches are installed to operate motors automatically, a bull's-eye lamp and warning gong operated by separate float switches shall be installed to indicate unusually high liquid levels caused by failure of pumps or equipment. A cutout switch shall be installed to prevent continuous operation of the gong, but the indicating lamp shall remain lit until the condition has been remedied. (*Omit lamps and gongs if overflow will cause no damage.*)

V. Gasoline Engines. (*Generally used as standbys.*)

Engines shall develop sufficient horsepower at ____ r.p.m. (*same as pump*) to operate the pumps to which they are connected continuously for 24 hr. at pump capacity specified in paragraph II. Engines shall be equipped with standard flywheel and pedestal-type housing, front support, flywheel ring gear, intake and exhaust manifolds, water inlet and outlet pipes, water-circulating pump, oil-pressure gage, Pierce governor, magneto ignition system, gasoline carburetor, throttle and choke controls, 6-volt starter and switch, 6-volt generator and ammeter, fan assembly, oil-bath air cleaner, power unit front support, standard radiator assembly, heavy-duty clutch, sheet-metal housing, gasoline tank of size standard with manufacturer, muffler crimped-type, lubrication oil filter, fuel pump, battery

and trickle charger, and complete starting equipment. Engines shall be Le Roi, Continental, Climax, Wisconsin, or approved equal.

VI. Diesel Engines. (*Used where electric power is not available or as standbys.*)

Engines shall develop sufficient horsepower at ____ r.p.m. (*same as pump*) to operate the pumps to which they are connected continuously for 24 hr. at pump capacity specified in paragraph II. Engines shall be equipped with (*use applicable accessories specified for gasoline engines*). Engines shall be Buda, General Motors, Ingersoll-Rand, Allis Chalmers, or approved equal.

VII. Portable Pump.

Portable pumps for emptying tanks of sewage and sludge shall be 3-in. *or* 4-in. single-plunger *or* double-plunger type complete with $3\frac{1}{2}$-hp. (*single plunger*) *or* 8-hp. (*double plunger*) gasoline engine and pneumatic tires.

The pump shall have a capacity of ____ gal. per hr. with a suction lift of 10 ft. and a capacity of ____ gal. per hr. with a suction lift of 20 ft. It shall have a maximum suction lift of 25 ft. and a maximum discharge head of 40 ft. (*single plunger*) *or* 60 ft. (*double plunger*).

The contractor shall furnish a heavy tarpaulin cover with lacing to cover the unit. The contractor shall also furnish ____ ft. of ____in. hose.

VIII. Sump Pump. (*For pits, basements, dry pit of pump house, etc.*)

The sump pump shall have a capacity of ____ gal. per hr. against a discharge head of ____ ft. while operating at a speed of ____ r.p.m. It shall be complete with automatic float control and be suitable for a sump depth of 2 ft. The motor shall be ____ hp. and capable of operating satisfactorily with ____ phase, ____ cycle, ____ volt power with temperature rise not to exceed 40° C.

Pipe connections shall be $1\frac{1}{4}$ in. in diameter. minimum. Materials for various parts of the pipe shall be as follows:

Column	*Specify one*	Seamless brass Bronze
Drive shaft		Precision steel chromium plated at bearing points
Bearing		Bronze heavily leaded for water lubrication
Volute	*Specify one*	Cast iron Bronze
Impeller	*Specify one*	Cast iron Bronze
Stand or foot piece	*Specify one*	Cast iron Bronze

The pump shall be as manufactured by Fairbanks-Morse Co. or approved equal.

IX. Lubrication.

Ample means of lubrication shall be provided for all bearings and parts where required. Alemite industrial-type fittings or approved equal shall be used for grease lubrication.

X. Pump and Motor Characteristics Curves.

The contractor shall furnish ____ sets of characteristics curves and data describing the units for approval.

XI. Basis of Payment.

Specify that the contractor be paid at unit or lump sum price called for in the contract.

WATER

OUTLINE FOR A COMPLETE WATER-WORKS SPECIFICATION

I. Items Included.

Title page.

Table of contents.

Invitation to bidders, *see p. 1.*

Proposal forms, *see pp. 4 and 7.*

Contract forms, *see pp. 10 and 13.*

Performance bond.

General conditions, *see p. 18.*

Detail specifications:

Preparation of site, *see p. 29.*

Excavation and grading for structures, *see p. 31.*

Drainage pipes and gutters, *see p. 157.*

Drainage structures, *see p. 160.*

Sewer pipes, *see p. 163.*

Sewer structures, *see p. 167.*

Equipment for water-treatment plant, *see pp. 187 to 196 incl.*

Water distribution, *see p. 197.*

Pumps, *see p. 190.*

Painting, *see p. 156.*

Structural, *see pp. 30 to 86 incl.*

Buildings *as required.*

Roads, *see pp. 87 to 134 incl.*

Electrical as required.

Heating and ventilating as required.

Plumbing as required.

II. Special Conditions. *See also p. 26.*

Services of Manufacturer's Engineer. During the first year of operation the supplier of the following equipment shall furnish the services of a competent representative for the number of days and trips listed below.

Item	Man-Days	Trips
Wash water rate controller	1	1
Filter water rate controller	2	1
Recording gages	1	1
Chlorinator	2	1
Pumps	1	1
Meters	2	1
Constant-rate feed hoppers	1	1
Proportioning chemical feeders	4	2
Softeners	3	3
Spiractor	8	4
Sludge-removing devices	2	1
Precipitator or accelerator	20	4
Pressure filters	2	2

Specify additional as required.

The purpose of this service is to instruct the plant operating personnel in the maintenance and care of the equipment and to conduct tests and make recommendations for producing the most efficient results. A report shall be submitted to the chief operator or superintendent and the engineer by the manufacturer after each visit, stating the operating conditions and results of the tests, and making suggestions and recommendations for improvement in operations. The actual dates when such services are to be given will be arranged with the manufacturer by the superintendent or the engineer, but the first trip shall be made during the initial operation of the completed plant. The price bid for the equipment shall include the complete cost of services specified above.

III. Guarantees.

Upon completion of the work and before the release of retained percentages, the contractor shall furnish a bond or bonds covering the following items of work for the periods stated as a guarantee of satisfactory operation for the equipment and the correction of any defects in the work, material, or equipment furnished by him.

Description	Amount of Bond	Period
Waterproofing	$____	2 years
All mechanical equipment	$____	1 year
Piping	$____	1 year
Wells	$____	1 year
Roofing	$____	3 years
Other items	$____	____

IV. Delimitation of Work.

Service contractors (*electrical, heating, plumbing, etc.*) shall make all connections to equipment and shall mount and test all controls. Manufacturers shall furnish all controls with equipment unless otherwise specified. (*"Scope of Work" clauses in electrical, plumbing, heating and ventilating, etc., and similar clauses in equipment specifications should be so written that there will be neither overlapping nor omission of any work.*

Note: specify additional clauses as required.

WELLS

I. Scope of Work.

This work shall include furnishing, installing, and painting wells, pumping equipment, controls, and piping as shown on the plans or specified herein; it shall also include furnishing working and shop drawings, testing, and operation services as specified under "General Conditions."

II. Permits.

The contractor shall obtain all permits and comply with all requirements of ____ *(name of body controlling groundwater resources).*

III. Capacity of Individual Wells.

(Where subsurface water conditions are unknown, the engineer should have a test well drilled and a flow test made before filling in the capacities, type of well to be used, and expected depth limits below. The test well is to be included as one of a finished group of wells if feasible.)

The capacity of individual wells shall be guaranteed as below to deliver a minimum supply as follows:

Well ____ ____ g.p.m.
Well ____ ____ g.p.m.

The engineer will accept variations of 5% in rated capacity yield from the stipulated capacity of each well; however, in no case will a total yield from all wells of less than ____ g.p.m. be accepted. *(Test well and guarantee are often omitted.)*

IV. Well Construction.

Wells shall be of *(give type: single-cased, double-cased with gravel wall, double-cased to rock and unlined below). (See "Data Book—Design.")* Water is expected to be developed from a water-bearing stratum from ____ ft. to ____ ft. below surface.

(If well is to be developed by surging, specify that the surging and developing are to continue until no sands come through the screen at full capacity of well.)

(If double-cased gravel-wall well is used, specify that provisions shall be made for placing additional gravel in walls.)

V. Gravel.

Gravel for gravel-wall wells shall be washed, well-rounded, graded from 100% by weight passing a $\frac{1}{2}$-in. sieve to 0 to 5% by weight passing a No. 10 sieve.

VI. Casings.

Permanent casings shall be steel pipe conforming to A.S.T.M. Spec. A-53, *or* wrought-iron pipe conforming to A.S.T.M. Spec. A-72 *(use wrought iron or steel according to proved soil and water conditions and local practice)*, either welded joints *or* screw coupling. Couplings shall be standard drive well couplings with long recessed threads so that pipe will butt. *For weight and sizes, see plan.*

(Specify applicable portions of specification for welding under "Structural Steel.") Weld details shall be as shown on the plans.

(Where no plan accompanies this specification, call for steel pipe to be A.S.T.M. Spec. A-53 schedule 40 pipe or wrought iron to be A.S.T.M. Spec. A-72 "standard weight" pipe; minimum diameter as required by pump size or capacity test.)

VII. Screen.

Screen shall be of Everdur metal of continuous "V" slot or louvre construction as made by Edward E. Johnson, Inc., or A. D. Cook Co., or equal. Slot area shall be selected by the contractor to conform with water-bearing stratum encountered. (*Length to be as required by local condition, generally 20 ft.*)

VIII. Samples.

One sample of material drilled through at each change in stratum shall be obtained by the contractor, sealed, marked as to depth, and given to the engineer. Contractor shall furnish any other samples required by proper authorities other than the owner.

(*Specify samples to be taken as indicated in specification for "Borings for Structures."*)

IX. Capacity Test.

Upon completion of each well between the limits of depth specified in paragraph IV, the contractor shall conduct a continuous pumping test at capacity specified in paragraph III, furnishing all equipment and measuring devices, until such time as the ground-water table becomes stabilized. Such test shall be made for each well to establish the pumping level at full capacity.

The contractor shall continue pumping for 2 hr. without stopping at decreased rates with throttled pumps to find data for drawdown curve. (*Needed for future design.*)

Upon completion of all wells, the contractor shall test all wells simultaneously by the same procedure as above. The period of test shall be twice that for individual well tests.

X. Well Pumping Equipment.

(*If capacity, head, and type of pump are not known, exclude this item and take separate bids at later date.*)

The contractor shall furnish and install in each well one turbine well pumping unit, electrically driven, each unit to deliver rated capacity of well. Each unit shall conform to the applicable portions of specifications for "Water Pumps." (*Specify auxiliary power if required.*)

Each pump shall have a 10-ft. suction attached; the top of the bowls shall be set 5 ft. 0 in. minimum below the pumping level.

The contractor shall furnish and install a pressure gage where shown on plans, a drawdown gage, tubing and air pump, and (*if automatic operation is required*) a pressure regulator suitable for minimum differential setting of ____ lb. and maximum of ____ lb.

All electrical connections, including those to power lines and to motors and controls and setting of controls, shall be made by others. (*Include in electrical specification.*)

Before the contractor places orders for pumping equipment he shall submit to the engineer full construction data and operating curve sheets showing kilowatt consumption, pump efficiency, horsepower input, and overall efficiency. The approval of the engineer shall be obtained before pumping equipment is ordered.

XI. Piping and Valves.

The contractor shall furnish and install all water and drainage piping and valves shown on the plans. All piping and valves shall conform with applicable portions of specifications for "Water Distribution System" and "Sewer Pipes." (*Specify limits of piping work under this contract.*)

XII. Meters.

The contractor shall furnish and install at each well in locations shown on plans a meter with a range capacity capable of accurately measuring and recording the flows of water. Meters to be Simplex, Sparling, or approved equal. (*Specify size and type of meters according to plan or design requirement.*)

XIII. Guarantee.

The contractor shall guarantee that the water production as shown by the official test is not a temporary condition, and if, at any time during a period of one year from the date of the official test, in the opinion of the engineer, the water production of this system shall have become reduced and below the official rated production paid for, the contractor shall make another official test in cooperation with the engineer to determine the actual capacity at that time. The pumping level during this test shall not be lower than when the capacity test, paragraph IX, was made. Should the capacity yield at that time be less than the official rated capacity of the well by more than 5%, the contractor shall bear the costs for making the test, including engineer's costs. Should the capacity yield be within 5% of the rated capacity of the unit, any such expenses encountered by the contractor for making the test shall be borne by the owner.

If the test should prove a reduction in yield of more than 5%, and unless such reduction is caused by lowering of the ground-water level by influence outside the control of the contractor, the contractor shall, without cost to the owner, do whatever is necessary to bring the well units to their rated capacity. Should the contractor fail, after due effort, to reinstate the well capacity he shall refund to the owner the monies received under this contract in the ratio of the deficiency to the rated capacity.

XIV. Basis of Payment.

Specify that the contractor be paid at lump sum price called for in contract for complete well as specified.

Specify debit and credit clauses if the contractor fulfills capacity test requirements at less depth than specified or if contractor must drill deeper than specified depth to meet capacity test requirements.

WATER PUMPS

I. Scope of Work.

This work shall include furnishing, installing, and painting pumps, motors, standby motors (*if used*), shafting, flexible couplings, base plates, anchor bolts, and all controls; it shall also include furnishing shop and working drawings, testing, and operation services as specified under "General Conditions."

II. Pumps.

Horizontal Centrifugal. (*Fill in blanks from designs.*)

No.	Type	Operating Condition	Size of Suction (S.) Discharge (D.)	Manufacturer
	Single-stage Multistage	__ g.p.m. against total dynamic head of __ ft., speed __ r.p.m.	S. __ in. D. __ in.	Fairbanks-Morse Co. Gardner-Denver Co. Chicago Pump Co. Dayton Dowd Co.

Pump casings shall be of cast iron, horizontal split design, cast so that the upper part of the casting may be removed for inspection of rotary parts without disturbing pipe connections or pump alignment; impellers of bronze, one-piece castings; shafts of high-grade steel; flexible couplings and bearings for shaft connecting pump and motor; continuous cast-iron base plate for pump and motor.

Deep-Well Turbine. (*Fill in blanks from design.*)

No.	Type	Operating Conditions	Size of Bowls	Manufacturer
	Water *or* oil lubricated	__ g.p.m. at __ lb. per sq. in. at __ ft. elevation at speed of __ r.p.m.	To fit in casing of __ diameter __ in.	Pomona Pump Co. Fairbanks-Morse Co. Layne-Bowler, Inc.

Discharge column pipe lengths shall not exceed 10 ft.; pipe shall be equal to A.S.T.M. Spec. A-53, joints flanged or screw threaded. Shaft shall be of steel of high torsional strength with a guiding spider every 60 ft. (*If water lubricated, chromium plate shaft*); pump bowls shall be of dense close-grained cast iron. Impellers shall be of bronze, one-piece castings.

III. Electric Motors and Controls.

(*Use applicable paragraphs in specification for "Sewage Pumps."*)

IV. Gasoline Engines. (*Generally used as standbys.*)

(*Use applicable paragraphs in specification for "Sewage Pumps."*)

V. Diesel Engines. (*Used where electric power is not available or as standbys.*)

(*Use applicable paragraphs in specification for "Sewage Pumps."*)

VI. Lubrication.

Ample means of lubrication shall be provided for all bearings and parts where required. Alemite industrial-type fittings or approved equal shall be used for grease lubrication.

VII. Pump and Motor Characteristic Curves.

The contractor shall furnish ____ sets of characteristic curves and data describing the units for approval.

VIII. Basis of Payment.

Specify that the contractor be paid at unit or lump sum price called for in the contract.

RAPID SAND FILTERS, SAND AND GRAVEL

I. Scope of Work.

This work shall include furnishing and placing sand and gravel as shown on plans and specified below.

II. Sand.

Sand shall be washed and graded and shall consist of hard, sharp, uncoated siliceous grains free from soft particles, clay, and other deleterious substances.

Sand shall have an effective size between 0.40 mm. and 0.55 mm. with no particles greater than 0.8 mm. and a uniformity coefficient not exceeding 1.65. *See p. 3-16, "Data Book—Design," for determination of effective size and uniformity coefficient.*

Sand shall be so placed as to avoid segregation of fine and coarse particles.

III. Gravel.

Gravel shall consist of hard, durable, clean material, screened and washed to remove all fine material and dust and to retain only the sizes specified.

Gravel shall be placed in layers, the number and thickness of which are shown on the plans. (*See "Data Book—Design."*)

IV. Approval of Materials.

Before use, samples of sand and gravel shall be submitted for test, and no material shall be used until approved.

V. Supplier's Certificate.

Sand and gravel may be used if accompanied by supplier's certificate of compliance, pending any tests which may be made by the engineer.

VI. Tests.

Laboratory or Plant Tests. The methods of test shall be the latest revision of the following:

		Number of Tests
Coarse aggregate (gravel)		
Sieve analysis	A.S.T.M. C-136	One from samples submitted in advance. One for each size from each source and if there is any apparent change.
Immersion in concentrated, warm hydrochloric acid for 24 hr., maximum loss of 5% of original weight.		
Fine aggregate (sand)		
Sieve analysis	A.S.T.M. C-136	
Immersion in concentrated, warm hydrochloric acid for 24 hr., maximum loss of 5% of original weight.		
Effective size and uniformity coefficient.		2 per bed.

WASH WATER RATE CONTROLLER AND REGISTER-INDICATOR-RECORDER

(*Used when wash water is being supplied by gravity method, tank, or standpipe. May be omitted and replaced by gate valve when wash water is being pumped at constant rate into filter.*)

I. Scope of Work.

This work shall include furnishing, installing, and painting ____ (*give no.*) ____ (*give size*) wash water rate controllers provided with meter body and device to actuate a register-indicator-recorder to be mounted on a panel located as shown on plans; it shall also include furnishing working and shop drawings, testing, and operation services as specified under "General Conditions."

II. Rate Controller.

(*May be hydraulically operated or direct-acting type with scale beam.*)

The rate controller shall be suitable for a capacity range of ____ to ____ million gallons per day with a normal working capacity of ____ million gallons per day. The loss of head across the controller at the normal rate of flow shall not exceed ____ in. The controllers shall maintain the rate for which they are set throughout the operating head on the filter with not more than 3% variation from the mean. Inlet vent holes shall be bronze bushed, and the Venturi throat shall be bronze lined with machined finish. The inlet and outlet ends shall be flanged, faced, and drilled *or* bell and spigot Class D according to American Standard for Standard Flanged Fittings.

(*If hydraulically operated, specify.*) The rate controller shall be hydraulically operated Venturi type with pilot valve for control of the hydraulic cylinder. The hydraulic cylinder operating the valve of the controller shall be suitable for operation on water pressure of ____ lb. per sq. in. Equipment shall be that made by Builders Iron Foundry, Simplex Valve & Meter Co., International Filter Co., or approved equal.

(*If direct-acting type with scale beam, specify.*) The rate controller shall be direct-acting Venturi type with scale beam. The scale beam shall be graduated to read the flow directly in million gallons per day. Equipment shall be that made by Builders Iron Foundry, Simplex Valve & Meter Co., or approved equal.

III. Register-Indicator-Recorder.

The register-indicator-recorder shall have a 10-in. or larger diameter chart, have an indicator arc, and be suitable for flush mounting on a panel located as shown on the plans.

The charts for the recorder shall be 7-day charts graduated uniformly from 0 to at least ____ million gallons per day.

The totalizer, indicator, and charts shall read direct without the use of multipliers other than the addition of zeros. The mechanism shall be actuated by a synchronous motor clock suitable for operation on ____ volt, ____ phase, ____ cycle current. The relay unit for the register-indicator-recorder (*if required*) shall be mounted on the back of the panel.

The mechanism shall be furnished with 150 charts of good-grade paper, duplicate pen for recorder, ink, oil, and all special tools for removing or adjusting any parts. The necessary mercury for the meter body shall be provided. Equipment shall be that made by Builders Iron Foundry, Simplex Valve & Meter Co., International Filter Co., or approved equal.

FILTERED WATER RATE CONTROLLERS

I. Scope of Work.

This work shall include furnishing, installing, and painting ____ *(give no.)* ____ *(give size)* filtered water rate controllers; it shall also include furnishing working and shop drawings, testing, and operation services as specified under " General Conditions."

II. Rate Controller.

(May be hydraulically operated or direct-acting type with scale beam.)

Use applicable portions of specification for "Wash Water Rate Controller."

LOSS-OF-HEAD AND RATE-OF-FLOW GAGES

(*Measures loss of head and rate of flow through filter. One set of gages for each filter bed unit.*)

I. Scope of Work.

This work shall include furnishing, installing, and painting ____ combination loss-of-head and rate-of-flow gage units; it shall also include furnishing working and shop drawings, testing, and operation services as specified under "General Conditions."

II. Gages.

The recording rate-of-flow gages shall not be less than 10 in. in diameter, and the loss-of-head and rate-of-flow gages shall be the same size mounted on a sheet-steel case with dull black finish suitable for mounting on panel *or* operating table. Each gage shall be provided with a diaphragm pendulum unit or equal for connection with the Venturi tube of the filtered water rate controller. Electric light shall be provided to illuminate the gages. Suitable cable and counterweights shall be provided between the gages and the diaphragm units.

The recording rate-of-flow gages shall be suitable for all rates of flow up to ____ million gallons per day and shall be graduated to read in million gallons per day and shall be operated by synchronous motor clocks suitable for operation on ____ volt, ____ phase, ____ cycle current. One hundred and fifty 7-day charts uniformly graduated shall be provided.

The loss-of-head gages shall be graduated to read from 0 to 12 ft.

Equipment shall be that made by Builders Iron Foundry Type ____, International Filter Co. Type ____, Simplex Valve & Meter Co. Type ____, or approved equal.

HYPOCHLORINATOR

(Used for small installations instead of chlorinator.)

I. Scope of Work.

This work shall include furnishing, installing, and painting hypochlorinator, crock for hypochlorite solution, strainer (*motor and switch for electrically operated hypochlorinator only*), chlorine resistant solution line and diffuser, and other necessary chlorine valves, piping, hose, and spare parts. (*The following sentence applies only to automatic hypochlorinators.*) It shall also include furnishing and installing Venturi tube, pitot tube, *or* flow orifice and converter and necessary piping and accessories from metering device to hypochlorinator.

The work shall also include furnishing working and shop drawings, testing, and operation services as specified under "General Conditions."

II. Hypochlorinator.

The hypochlorinator shall be manual *or* automatic control, electrically *or* water operated, designed to feed hypochlorite solution to water. The hypochlorinator shall have a capacity of 5 lb. of chlorine per 24 hr. when running continuously using a hypochlorite solution of 1% strength. The hypochlorinator shall be provided with adjustment for dosage as well as for varying the strength of the hypochlorite solution.

Equipment shall be that manufactured by Wallace & Tiernan Co., Proportioneers, Inc., or approved equal.

CHLORINATOR

I. Scope of Work.

This work shall include furnishing, installing, and painting manual *or* automatic chlorinator complete with all accessories and piping, including the following: black-extra heavy wrought-iron chlorine gas header, chlorine-pressure-reducing valve, water-pressure-regulating valve, chlorine resistant solution line and diffuser, chlorine meters, chlorine valves, header valves, manifold and pipe hanger supports, copper tubing flexible connections, platform scale, and all piping, hose, and conduits and appurtenances. (*The following sentence applies only to automatic chlorinators.*) The work shall also include furnishing and installing Venturi tube, pitot tube, *or* flow orifice and differential converter and necessary piping and accessories from metering device to chlorinator.

(*When difference in pressure between water supply to chlorinator and point of chlorine application is not large enough to operate chlorinator, a booster pump is necessary.*) The work shall also include furnishing and installing booster pump and motor and necessary piping and valves as shown on plan, and furnishing duplicate spare parts for all glassware, one testing outfit for chlorine residual, and chlorine gas masks, each with extra canister. The work shall also include furnishing working and shop drawings, testing, and operation services as specified under "General Conditions."

II. Chlorinator.

The chlorinator shall be ____ lb. per 24 hr. solution feed, visible vacuum-type chlorinator, manual *or* automatic type, as manufactured by Wallace & Tiernan Co., or approved equal. Meters shall be furnished to dose between a minimum rate of ____ lb. per 24 hr. and a maximum rate of ____ lb. per 24 hr. with an accuracy within 4%. (*The following applies only to automatic chlorinators.*) The automatic chlorinator shall be so designed as to permit of manual operation.

III. Booster Pump.

The booster pump shall be furnished by the manufacturer of the chlorinator. It shall be of adequate pumping head to make possible application of chlorine solution under all pressures that may be expected. The maximum pressures expected to occur at the inlet and discharge mains are ____ and ____ lb. per sq. in., respectively. *Bidders must acquaint themselves with the hydraulic conditions and submit equipment which they recommend as appropriate.*

IV. Platform Scale.

The platform scale shall be of ____ lb. capacity with (*small installations, under 1500 lb.*) portable platform approximately ____ in. by ____ in., equipped with standard beam; *or* with (*large installations, over 1500 lb.*) skeleton frames, coping angles, etc., for recessing scale in floor. The scale shall be dial indicating with platform approximately ____ in. by ____ in. The dial shall be graduated to ____ lb. (*weight of chlorine gas exclusive of cylinders*), and the additional weight on the scale shall be carried by the tare and capacity beam.

The scale shall be that made by Fairbanks-Morse Co., Howe Scale Co., Toledo Scale Co., or approved equal.

V. Testing Outfit.

The testing outfit shall include one chlorine comparator, complete with color disk, prismatic eyepiece, ten 26-mm. test tubes, and 100 cc. of orthotolidine solution. The testing outfit shall have a range for residual chlorine from 0.05 to 1.0 p.p.m. It shall be that made by Wallace & Tiernan Co. or approved equal.

WATER-DISTRIBUTION SYSTEM

I. Scope of Work.

II. Excavation and Backfill.

(*Insert applicable provisions of specification for "Excavation, Trenching, and Backfilling for Utility Systems."*)

III. Cast-Iron Bell and Spigot Pipe and Fittings.

(*Where water is of a corrosive nature, specify cement lining; otherwise specify coal-tar coating.*)

All pipe shall be cast iron except as otherwise shown on plans.

Pipe and fittings shall conform to the latest revision of Fed. Spec. WW-P-421 for the class called for by the plans *or* A.S.A. Spec. A21.2, latest edition, of equivalent strength.

The contractor shall state the credit or debit involved if permitted to furnish pipe based on design given in "Manual for the Computation of Strength and Thickness of Cast Iron Pipe," approved by the American Standards Association, December, 1939. The contractor's schedule of pipe thicknesses shall be submitted to a specialist engineer selected by the owner for check, and the contractor shall allow in his estimate the sum of 5¢ per foot of pipe to cover the cost of checking.

Cement Mortar Lining shall conform to the American Standards Association Spec. A21.4, latest edition, and shall be given a full coat of approved bituminous paint with exterior covered by an opaque coat of tenacious, weather-resistant whitewash.

Alternative. The contractor shall state the credit applicable if coal-tar coating is substituted for cement mortar lining.

Coal-tar coating shall be uniformly applied inside and out by dipping the heated pipe and fittings twice in a tank or vat of hot gas-house coal tar or coke-oven coal tar which shall be as defined in the latest revision of A.S.T.M. Spec. D-8 and the following requirements: moisture, not over 0.7%; matter insoluble in benzol, not less than 5% or more than 20%.

Laying.* Pipe, fittings, valves, and hydrants shall be carefully handled to avoid damage, and while they are suspended over the trench before lowering they shall be inspected for defects and rung with a light hammer to detect cracks.

Before pipe is laid, all dirt shall be removed from inside and all lumps, blisters, excess coal tar, dirt, oil, grease, and moisture shall be removed from inside the bell and from outside the spigot end.

After pipe is laid, care shall be taken to avoid the entrance of dirt or water from the trench by the use of tight bulkheads.

Jointing. All joints shall be calked with lead unless otherwise permitted by the engineer. The spigot end shall be centered in the bell, and the rear portion of the annular space shall be tightly packed with braided hemp or untarred twisted jute, leaving a space of $2\frac{1}{4}$ in. in depth for lead in pipe of 20-in. diameter or less; $2\frac{1}{2}$ in. for 24-in., 30-in., and 36-in. pipe; and 3 in. for larger pipe.

* See also A.W.W.A. Spec. 7-D.1, 1938.

Lead for calking shall be common desilverized lead conforming to A.S.T.M. Spec. B-29-40T.

After joint is poured and when lead has cooled to the temperature of the pipe, the lead shall be calked until thoroughly compacted, making watertight joints without overstraining the bells.

Alternative. The contractor shall state credit or debit applicable if sulfur compound or cement jointing is used instead of lead.

Sulfur Compound Joints. Compound for pipe joints shall be "Hydrotite," "Leadite," "Teague-Mineralead," or approved equal.

Heating of compound and pouring of joints shall be done in strict accordance with manufacturer's directions.

Yarning. Square braided hemp or jute shall be tightly calked in joint space, leaving not less than $2\frac{1}{2}$-in. depth for compound poured in bells of pipe 24 in. in diameter and smaller; $2\frac{3}{4}$ in. for 30-in. and 36-in. pipe; $3\frac{1}{2}$ in. for 48-in. pipe; and 4 in. for 54-in. and 60-in. pipe.

Portland Cement Joints. All cement shall be of approved brand complying with current specifications of A.S.T.M.

Joints shall be tightly packed with braided hemp or jute of untarred twisted jute, leaving a space not less than 3 in. in depth for cement calking.

After yarning, the joint space shall be filled with neat cement barely moistened (about $\frac{1}{4}$ pt. of water to 1 qt. of cement), which shall be calked by competent workmen until it is thoroughly compacted without overstraining the bell to make a watertight joint. The cement shall be so dry that it will ring with a metallic sound while being calked.

IV. Cast-Iron Flanged Pipe and Fittings.

(*Specify for connections to tanks and pumps and where there is vibration.*)

Flanged pipe shall meet the requirements of the American Water Works Association for thickness and diameter and shall be of the size and strength shown on the plans. Flanges and fittings shall conform to American Standards Association practice for 125 lb. pressure unless otherwise shown.

Jointing. Gaskets shall be Rainbow, Durable Garlock, or approved equal. Gaskets 8 in. round and smaller shall be $\frac{1}{16}$ in. thick; over 8 in. round they shall be $\frac{3}{32}$ in. thick. Bolts shall have rough square heads and hexagonal nuts made to American Standard rough dimensions and shall be chamfered and trimmed. Bolts shall be tightened so as to distribute evenly the stress in the bolts and bring the pipe in alignment.

V. Galvanized Wrought-Iron Pipe and Fittings.

(*Use where exposed to corrosive conditions such as the presence of sea water, salt air, or flue gases.*)

Pipe shall conform to A.S.T.M. Spec. A-72-39. Fittings shall include elbows, ties, courses, branches, bushings, plugs, unions, and reducers and shall be malleable-iron screwed fittings. All pipe and fittings shall be galvanized to meet the requirements of A.S.T.M. Spec. A-153-42T.

Jointing. Threads shall be neatly cut with sharp tools, and the jointing procedure shall conform with best practice. Before jointing, all scale shall be removed from pipe by some suitable means, as pounding. After cutting, all pipe shall be reamed. All pipe shall be screwed together with an application of graphite and engine oil or other approved pipe compound applied to all threads, and, once a joint has been screwed up, it shall not be backed off unless the threads are recleaned and new compound applied. This application shall be neatly made, and all oil, graphite, and dirt shall be thoroughly wiped off the inside of every joint.

VI. Asbestos-Cement Pipe.

(*Equivalent hydraulically to cement-lined pipe with approximately equal life, but not so rugged.*)

The contractor shall state the credit or debit applicable if asbestos-cement pipe is substituted for cast-iron pipe.

Pipe shall conform to the latest revision of Fed. Spec. SS-P-351 and shall be of strength specified for cast-iron pipe.

Installation shall be in accordance with manufacturer's directions.

Cast-iron fittings for use with asbestos-cement pipe shall conform to Fed. Spec. WW-P-421 or to A.W.W.A. Standard of equivalent strength.

VII. Wood-Stave Pipe, Machine Made.

(*Maximum size manufactured usually is 30 in. in diameter.*)

Pipe shall be of the quality produced by the Federal Pipe and Tank Co., Michigan Pipe Co., or approved equal, and shall comply with the requirements as to size and strength called for by the plans.

Care in Handling. The contractor shall be responsible for pipe damaged by his operations.

Installation. Pipe shall be laid with coupling or mortise ends of sections pointing forward in the direction of laying and shall be thoroughly cleaned before joining.

The driving plug shall fit the end of the pipe so that it will have uniform bearing against the stave ends and shall be held firmly against the pipe when driving.

The tenon shall be inserted so as to fit around the entire circumference, and driving shall be started with light blows to make certain that this has been accomplished. When properly entered, the section shall be driven up tight against that previously laid.

The use of soap or similar lubricant on the tenons will be permitted to facilitate the joining.

Curves shall be laid by driving sections of pipe in straight and then springing pipe into proper alignment. Uniform curvature shall be accomplished by use of pipe lengths varied to suit conditions.

Pipe required to be cut in the field shall have wire securely stapled immediately back of the cut before cutting proceeds. The tenon end shall be accurately milled and finished with a wood rasp.

At curves, bends, tees, and ends, the pipe shall be properly blocked or braced to prevent movement when under pressure.

Tests for leakage shall be made with hydrostatic pressure up to 10% in excess of the head for which the pipe is banded and shall be maintained for 24 hr. unless otherwise approved by the engineer. Any running leaks that develop shall be closed.

VIII. Wood-Stave Pipe—Continuous. (*Erected in field.*)

Pipe staves, bands, shoes, and joints shall be of the quality and type produced by Federal Pipe and Tank Co., Michigan Pipe Co., or approved equal and shall comply with the requirements as to size and strength called for by the plans.

Erection. The ends of adjoining staves shall break joint at not less than 18 in. Staves shall be laid and driven in such a manner as to avoid any tendency to cause wind or twist in the pipe, and the required alignment and grade shall be maintained. Staves shall be well driven to produce tight butt joints, driving bars or other suitable means being used to avoid marring or otherwise damaging the staves in driving. In rounding out the pipe, care shall be exercised to avoid damage by chisels, mauls, or other tools. The pipe shall be rounded out to produce smooth inner and outer surfaces. Bands shall be accurately spaced and placed perpendicular to the axis of the pipe. Shoes shall be placed so as to cover longitudinal joints between staves and to bear equally on two staves as nearly as practicable. They shall be placed alternately on opposite sides of the pipe so as to be out of line and to cover successively at least two seams on each side in a uniform manner. Bands shall be hammered during the process of cinching. All metal work shall be handled with reasonable care so as to avoid injuring the coating. In hammering shoes into place, they shall be struck in such a manner as to avoid deformation or injury. After erection, all metal work shall be retouched, where abraded, with a suitable paint. At curves, bends, tees, and ends, the pipe shall be properly blocked or braced to prevent movement under pressure.

Testing. Tests for leakage shall be made with hydrostatic pressure 10% in excess of the head for which the pipe is banded; pressure shall be maintained for 24 hr. Before testing, water shall be admitted gradually, time being allowed for swelling of the staves before full pressure is applied. Any running leaks that develop shall be closed.

IX. Reinforced-Concrete Pressure Pipe.

Pipe shall be in accordance with A.W.W.A. Spec. 7B-T and shall be designed for heads shown on plans. Shop drawings and details of joint bends and branch connections shall be submitted for approval.

X. Steel Pipe.

Pipe shall conform to A.W.W.A. Spec. 7A.3 and 7A.4, A.S.T.M. Spec. A-53, or "Standard for Steel Pipe Lines for Underground Water Service" by Underwriters' Laboratories, Inc., published by the National Board of Fire Underwriters. Pipe ends shall be for joints specified below or as shown on plans.

Coatings. All pipe shall be coated inside and out with coal-tar enamel in conformity with A.W.W.A. Spec. 7A.5-1940 for pipe 30 in. or larger in size and 7A.6-1940 for pipe 4 to 28 in. in diameter. The contractor shall provide pipe ends with treatment suitable for type of field jointing to be used.

(Specify exterior and interior protection such as Gunite or cement mortar lining as the case requires.)

Specials and Fittings may be standard steel tube turns, or segmentally welded sections of the same material and thickness as the pipe.

Jointing. Field jointing may be by couplings of sleeve or split-sleeve type or by welding or as shown on plans. Sleeve couplings shall be Dresser or approved equal. Split-sleeve coupling shall be Vitaulic or approved equal. The space between pipe ends under the couplings shall be completely filled with bituminous compound.

Welded Joints. *(Specify applicable portions of specification for "Structural Steel.")* Weld detail shall be as shown on plans.

Installation. Every care shall be exercised in handling pipe to avoid damage to pipe or coating. Only padded slings or flatfaced padded hooks with long narrow throat for hooking into each end of pipe shall be used. Pipe shall be stored not over 4 tiers high with 1 in. by 12 in. wooden strips not over 4 ft. apart between layers.

Placing Pipe. Pipe shall be carried into position and not dragged. Pinch bars and tongs for aligning and/or turning the pipe shall be used only on the bare ends of the pipe. If poles are used as levers for removing skids across the trench, they shall be of wood with broad flat faces to prevent damage to pipe coating. If belt slings are used for lowering the pipe, care shall be taken so that, when the sling is withdrawn from under the lowered pipe, the wrapping will not be torn. The installation of couplings shall be made in accordance with the recommendations of the coupling manufacturer.

Jointing. After the pipe has been placed in the trench to the required line and grade, the contractor shall proceed without delay to make up each field joint as required and shall provide an adequate force of men and appliances to meet this requirement.

Joint Coating. Coal-tar primer and enamel material shall be the same as used for coating and lining the pipe.

Before field pressure testing, the interior welds of field joints shall be cleaned and primed. When dry, hot enamel shall be applied to provide coating of the same thickness as the pipe lining.

After pressure tests, exterior joints shall be cleaned, primed, and coated with hot enamel.

All couplings shall be cleaned and primed before installation. After installation, prime coat shall be retouched if necessary, and the exposed portion of pipe and coupling shall be coated with a coupler compound or coating recommended by the manufacturer of the pipe enamel.

XI. Valves, Hydrants, Corporation Cocks.

Altitude Valves shall be of the external pilot-operated, free-floating piston type. The main piston shall be operated without the use of direct-acting springs and levers. The valves shall open to full pipe line area, and shall close without hunting action. Opening and closing shall be cushioned to preclude shocks or jars which may cause water hammer. The action of the assembly shall be semi-throttling so that the piston gradually approaches its seat as the tank level rises. The altitude valves shall be capable of maintaining tank level to within ____ in. of the required high water elevation. The valves shall be controlled by an auxiliary pilot valve and needle valve permitting a range of adjustment of not less than ____ ft., so that any change in adjustment can be accomplished with-

out the necessity of removing springs or the use of special tools or other devices. The pilot valve must be easily accessible. Valves shall be as made by Golden-Anderson Specialty Co., or approved equal.

Working and Test Pressures. Valves shall be designed for a cold hydrostatic working pressure of ____ lb. per sq. in. and shall be shop tested to ____ lb. per sq. in.

Calibration. Altitude valves shall be shop calibrated, and calibration data shall be furnished.

Check Valves shall be standard iron body swing type with straightaway passageway of full pipe area. Valve shall be bronze mounted with self-adjusting leather-faced disc.

Gate Valves shall be iron body, fully bronze mounted, double disc, parallel seat valves with hob or flanged ends as called for by the plans. All buried valves shall be non-rising stem type with 2-in. square operating nuts and adjustable cast-iron valve boxes and covers suitable for pipe cover of ____ ft.

Gate valves shall open counterclockwise *or* clockwise. *(Optional; usually open counterclockwise.)*

Check and gate valves shall be A.W.W.A. Standard by Kennedy Valve Mfg. Co., R. D. Wood Co., Chapman Valve Mfg. Co., or approved equal.

Hydrants shall be cast-iron body, fully bronze mounted, suitable for a working pressure of 150 lb. per sq. in., and shall be in accordance with the latest specifications of the A.W.W.A.

Hydrants shall be constructed in a manner permitting withdrawal of internal working parts without disturbing barrel or casing. When used in cold climates, hydrants shall be provided with sliding frost cases or porous fill around barrel. Valve, when shut, shall be reasonably tight when upper portion of barrel is broken off. Valve opening shall be at least 4.5 in. in diameter, with net area of waterway at smallest part, with valves wide open, not less than 120% of valve opening. There shall be no chattering under any condition of operation.

Each hydrant shall be tested to a hydrostatic pressure of 300 lb. per sq. in. with valve in both open and closed positions.

The direction of opening shall be cast on head of hydrant.

Hose nipples shall be bronze or non-corrosive metal, and threads shall be "National Standard." Nipple caps shall be securely chained to the barrel.

Hydrants shall be painted one coat of red lead paint and two finishing coats of an approved paint of color directed by the engineer. The final coat shall be Sonneborn's Hydrant Enamel or approved equal. Make shall be R. D. Wood, Kennedy Valve Mfg. Co., or approved equal.

Air Valves shall be installed where called for on the plans. The work shall include the complete assembly, with tap, shut-off valve, blow-off, air valve, and piping with valve, fittings, and union all complete and ready for operation.

Air valves shall be of a type comprising a special float enclosed in the valve body with attached lever for opening and closing the air discharge port. Access to the ball float and interior discharge vent seat shall be provided by means of a bolted flange as made by Eddy Valve Co. or approved equal.

The design of the float and lever shall be such as to insure opening of valve port under maximum internal pressure. The assembly shall not leak nor shall the valve stick under service conditions.

(Specify size of valve required. For steel pipe lines include poppet valve as safeguard against collapse in case of break in main.)

Valve Boxes shall consist of cast-iron base, center section, and top section with cover which shall be marked "Water." The top section shall be adjustable for elevation and shall be set to allow equal movement above and below finished grade. The base shall be centered over the valve and shall rest on compacted backfill. The top of the base section shall be approximately on line with nut at top of valve stem, and the entire assembly shall be plumb.

Corporation Cocks shall be of the size shown on the plans. Inlet thread shall be Mueller or iron pipe type as directed, with flange union couplings or wiped joints for connections to lead goosenecks. Type to be Clow-National or equal.

Lead Gooseneck connections 1 in. and smaller shall be X-strong lead pipe. Connections $1\frac{1}{2}$ in. and larger shall be XX-strong lead pipe. Length of lead pipe shall be sufficient to allow upward sweep of at least 6 in.

XII. Hydrostatic Tests.

The contractor shall provide all necessary equipment and shall perform all work required in connection with the tests.

All pipe (except wood stave) shall be treated by hydrostatic pressure 50% in excess of the normal working pressure.

Each section tested shall be slowly filled with water, care being taken to expel all air from the pipes. If necessary, the pipes shall be tapped at high points to vent the air.

The required pressure as measured at the point of lowest elevation shall be applied for not less than $\frac{1}{2}$ hr., and all pipe, fittings, valves, hydrants, and joints shall be carefully examined for defects. Leaking lead joints shall be recalked and made tight. Sulfur compound or cement joints showing more than slight sweating shall be cut out and replaced and then retested. Other types of leaky jointing shall be made watertight.

Leakage shall be determined with the pipe under normal working pressure. Leakage test on sulfur compound joints shall be made between 30 and 40 days after pressure test. Cement jointing shall be aged at least 2 weeks before testing. Water shall remain in line under pressure during waiting period. All other types of joints may be tested when convenient.

No pipe installation will be accepted unless and until the leakage (evaluated on a pressure basis of 150 lb. per sq. in.) is less than 100 U. S. gal. per 24 hr. per mile per inch normal diameter for pipe of 12-ft. lengths, 75 U. S. gal. for 16-ft. lengths, and correspondingly varied for other lengths of pipe.

Evaluation of the actual leakage to the leakage under the assumed basic pressure of 150 lb. per sq. in. shall be calculated by the application of the ratio determined from the square root of the respective pressures.

XIII. Sterilization of Completed Line.

Before being placed in service the entire line shall be chlorinated. Chlorine may be applied by the following methods: Liquid chlorine gas-water mixture, direct chlorine gas feed, or calcium hypochlorite and water mixture.

The chlorinating agent shall be applied at the beginning of the section adjacent to the feeder connection and shall be injected through a corporation cock, hydrant, or other connection insuring treatment of entire line.

Water shall be fed slowly into new line with chlorine applied in amounts to produce a dosage of 40 to 50 p.p.m. Mains previously filled shall be treated to a concentrated dosage at intervals along the line and retained for a period of 8 hr. or more. A residual of not less than 5 p.p.m. shall be produced in all parts of the line.

During the chlorination process all valves and accessories shall be operated.

After chlorination, the water shall be flushed from the line at its extremities until the replacement water tests are equal chemically and bacteriologically to those of the permanent source of supply.

Liquid Chlorine. Chlorine gas-water mixture shall be applied by means of a solution-feed chlorinating device. Chlorine gas shall be fed directly from a chlorine cylinder equipped with suitable device for regulating the rate of flow and the effective diffusion of gas within the pipe. Calcium hypochlorite shall be comparable to commercial products known as H.T.H., Perchloren, and Maxochlor. A solution consisting of 5% of powder to 95% of water by weight should be prepared. The calcium hypochlorite and water mixture, first made into a paste and then thinned to a slurry, shall be injected or pumped into the newly laid line under the conditions specified hereinbefore.

XIV. Approval of Materials.

Manufacturer's Certificate. (*Omit if laboratory tests are required.*)

Materials may be used if accompanied by manufacterer's certificate of compliance, pending any tests that may be made by the engineer.

XV. Tests.

Laboratory or Plant Tests. Pipe and materials shall be tested for conformity with latest revisions of the following:

		Number of Tests
Cast-iron pipe and fittings	Fed. Spec. WW-P-421	Chemical analysis, each heat; hydrostatic test, each piece.
Cement mortar lining	A.S.A. A21.4	Not less than 1% of pipe. Hydrostatic test, each piece. Flexure test, 1 from each 100 pieces. Crushing test, 1 from each 300 pieces.
Wood stave	As specified by manufacturer	Inspection of material only.
Reinforced-concrete pressure pipe	A.W.W.A. 7B-T	One hydrostatic test at 28 days for each day's run.
Steel pipe	A.W.W.A. 7A.3 and 7A.4; Underwriters' Laboratories, Inc., Sp. I. 888 A.S.T.M. A-53	As called for in specification.
Bituminous coatings	A.W.W.A. 7A.5 and 7A.6	As specified for primer and enamels. Electrical inspection of each pipe.
Valves	A.W.W.A. 7F.1	Each valve.
Hydrants	A.W.W.A. 7F.3	Each hydrant.

Field Tests. Cast-iron and asbestos-cement hammer test shall be made for cracks.

All pipes and fittings shall be tested hydrostatically.

XVI. Basis of Payment.

Specify that the contractor be paid at unit or lump sum price called for in contract.

State work included and/or excluded under this price.

Give method of measurement.

If unit price, itemize price units. Call for bid prices on alternates thought desirable.

If lump sum, itemize basis of payment for extra work.

VIII

COSTS

ENGINEERING NEWS-RECORD (E.N.R.) COST INDEX TABLE

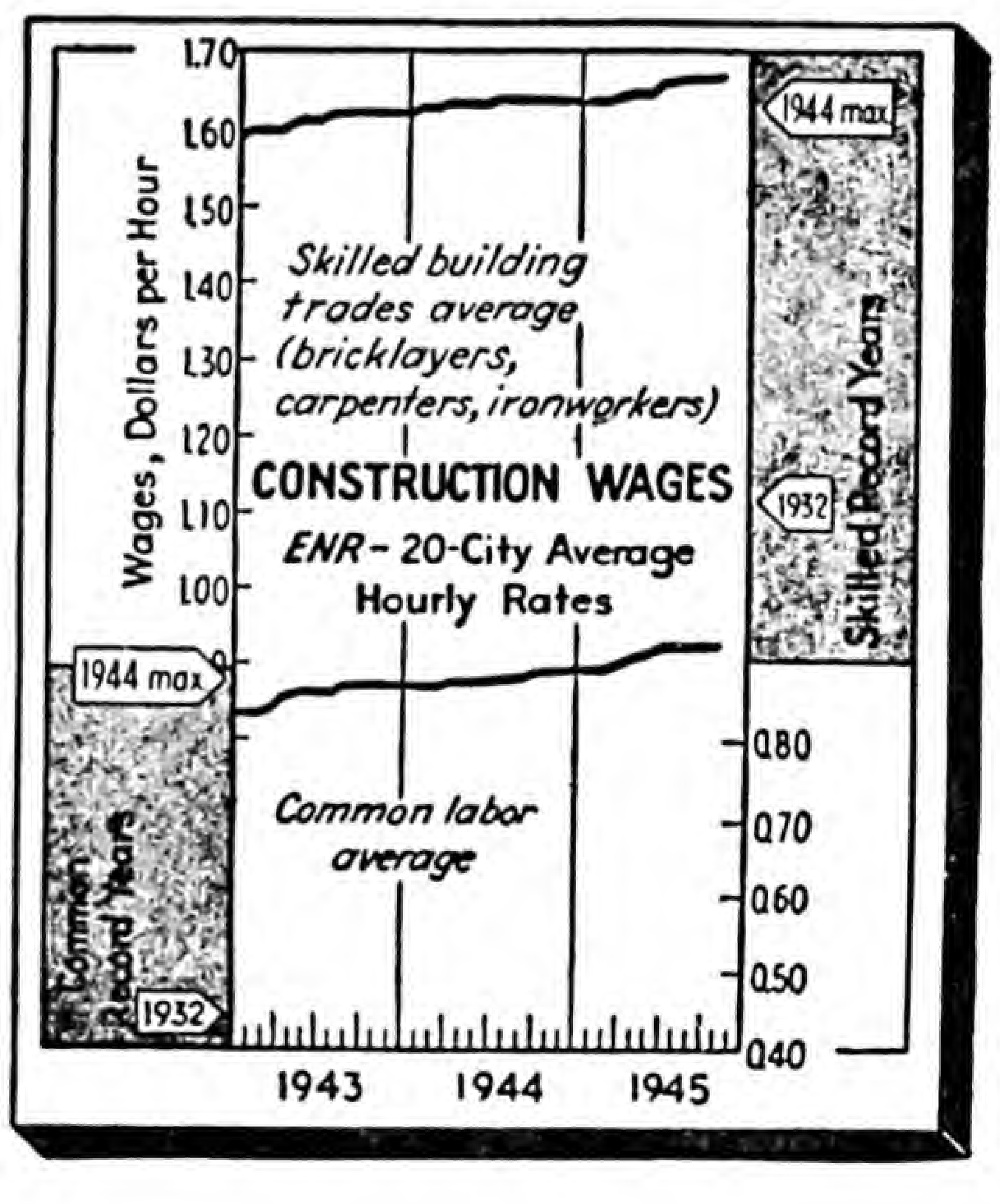
Year	Construction Cost Index	Building Cost Index	Material Cost Index
1913	100	100	62.0
14	88.56	91.9	53.2
15	92.58	95.3	56.2
16	129.58	130.9	91.2
17	181.24	166.8	125.0
18	189.20	159.1	113.2
19	198.42	158.8	105.2
1920	251.28	207.2	135.5
21	201.81	166.1	93.8
22	174.45	154.9	86.1
23	214.07	186.0	110.5
24	215.36	185.8	104.4
25	206.68	182.7	99.1
26	208.03	185.0	98.4
27	206.24	186.1	95.4
28	206.78	188.0	95.6
29	207.02	190.9	97.7
1930	202.85	185.4	90.7
31	181.35	169.4	81.3
32	156.97	140.9	71.6
33	170.18	147.8	78.9
34	198.10	166.7	91.7
35	196.44	165.8	90.9
36	206.42	172.2	93.6
37	234.71	196.2	105.8
38	235.86	196.8	100.3
39	235.51	197.4	98.8
1940	241.96	202.8	102.1
41	257.84	211.5	109.2
42	276.31	222.4	115.5
43	289.95	228.8	118.3
44	298.6	234.7	123.0
45	307.75	239.1	125.6
46	346.04	262.4	139.3
47	413.16	313.0	174.6
48*	451.68	338.6	188.9

* First 8 months' average.

SKILLED AND COMMON WAGE RATES—PER HOUR §

	Bricklayers	Carpenters	Structural Iron Workers	Hoisting Engineers	Plasterers	Common Labor: Building	Common Labor: Heavy Construction
Atlanta	$1.50	$1.25	$1.50	$1.25	$1.50	$0.40	$0.50
Baltimore	1.75	1.4375	1.80	1.625/1.80	1.725	.80	.80
Birmingham	1.75	1.25/1.50	1.625	1.375/1.625	1.65	.65	.65
Boston	1.625	1.50	1.675	1.50/1.875	1.667	1.00	1.00
Chicago	1.90	1.85	1.85	1.85	1.85	1.20	1.20
Cincinnati	1.825	1.60	1.725	1.45/1.60	1.75	.90	.90
Cleveland	1.875 *	1.575	1.875	1.875	1.875	1.085	1.125/1.155
Dallas	1.625	1.25	1.50	1.75	1.625	.60	.75/1.25
Denver	1.80 †	1.50 †	1.50 †	1.50/1.625 †	1.65	.825 †	.825 †
Detroit	1.725	1.50	1.825	1.675/1.825	1.775	1.00	1.00
Kansas City	1.75	1.575	1.70	1.675	1.75	.975	.90
Los Angeles	1.50	1.35	1.625	1.375	1.667	.875	.875
Minneapolis	1.625	1.44	1.625	1.50	1.625	.95	.95
New Orleans	1.625	1.375	1.625	1.55	1.50	.70	.80
New York	2.00 †	1.85 †	2.00	2.00 †	2.00 †	1.10	1.10
Philadelphia	2.00	1.58	1.90/2.00	2.25	2.00	.90	.90
Pittsburgh	1.90	1.75	1.75	1.8125	1.875	1.00	.90
St. Louis	1.90	1.70	1.90	2.00	1.75	1.00	1.00
San Francisco	1.875	1.50	1.75	1.50/1.75	1.75	1.00	1.00
Seattle	1.845	1.545	1.745	2.00	1.845	1.145	1.145
Montreal ‡	1.06	.96	1.01	.91	1.06	.61	.66

* Prevailing rate on government work.
† 7-hr. day.
‡ Cost-of-living bonus now included in basic wage.



E.N.R. skilled average (bricklayers, carpenters, ironworkers), $1.674.
E.N.R. common average, $0.917.
§ From *Engineering News-Record*, Oct. 4, 1945.

BUILDINGS—COSTS PER CUBIC FOOT *

Cu. ft. equals depth of building times width times height. Subtract for open courts, etc.

All prices are net field costs, material and labor only, for October, 1945, in the Metropolitan New York area. Costs do not include excavation, contractor's profit, architect's fee, temporary or permanent financing, insurance, title search, or clearing of site.

To arrive at the complete cost to owner, add 15 to 20% to net field costs.

For costs in other cities, see the table of Conversion Factors on p. 207.

It is stated in "The Dow Service Real Estate Valuation Calculator" that costs for 1939 are 79.7% of net field costs for October, 1945.

Type of Construction		Net Field Costs in Cents
	Apartment	
Semi-fireproof	2-story low-cost housing—complete with heat, light, plumbing, and painting	36.2†
Fireproof	2-story low-cost housing—complete with heat, light, plumbing, and painting	39.6†
Non-fireproof	5-story walkup—complete with heat, light, plumbing, and painting	38.5
Non-fireproof	6-story automatic elevator—complete with heat, light, plumbing, and painting	43.5
Fireproof	12-story modern Park Avenue type—high-class equipment including air conditioning	65.3
	Office (including light, heat, plumbing)	
Fireproof	20-story, side street—steel, concrete, and brick	59.5
Fireproof	10-story, large area stores—steel, stone, brick, 9 elevators, sprinklers	64.3
Fireproof	12-story, stores, 1st and 2nd floors—steel, stone, and brick	73.9
Fireproof	39-story —steel, brick, limestone exterior, 11 passenger and 1 freight elevators	92.6
	Hotel (including light, heat, plumbing)	
Fireproof	Up to 12 stories, commercial type, per room	4,000.0†
Fireproof	16-story, set back every other story—steel, stone, brick	77.4
Fireproof	39-story, setbacks—steel, brick, limestone and terra-cotta trim, 22 elevators, tile roofs	96.0
	Hospital (including light, heat, plumbing)	
Fireproof	7- and 15-story Bellevue type—steel, brick, stone, $\frac{1}{2}$ foundations on piles, $\frac{1}{2}$ on rock	66.0
Fireproof	12-story, professional, doctors' offices 1st to 6th floors, hospital 7th to 12th floors—no equipment	84.6
	School (including light, heat, plumbing)	
Fireproof	2-story central high school—steel, brick, limestone trim, roof partly tile	36.5
Fireproof	3-story junior and senior high school	46.7
Fireproof	7-story university-law type, 2 mezzanines—steel, brick, stone	71.4
	Church (including light and heat)	
Brick and stone	No steeple—add 2 cents for steeple	58.8
Fireproof	Steel, brick, stone—heat, kitchen equipment, organ, seating, air conditioning	103.8
	Theater (including light, heat, plumbing)	
Fireproof	1-story moving picture—steel and brick, stores each side entrance	33.8
Fireproof	4-story elaborate type—steel, brick, architectural terra cotta, no equipment	49.7

* From "The Dow Service Real Estate Valuation Calculator" (descriptions condensed).
† By author.

BUILDINGS—COSTS PER CUBIC FOOT (Continued)

Type of Construction		Net Field Costs in Cents
	Garage (including lights, no heat)	
Non-fireproof	1-story private 2-car—brick and wood	17.8
Non-fireproof	2-story standard ramp type—no basement, brick walls, steel girders on piers, steel frame for 2nd floor and ramp, wood roof on steel covered with metal ceiling, columns fireproofed	28.5
	Factory (including light and heat)	
Non-fireproof	1-story frame—ordinary mill construction	18.8
Non-fireproof	1-story concrete—simple conventional 4-wall construction, 1 hoistway	24.8
Fireproof	3-story concrete—basement and sub-basement	31.8
Fireproof	4-story steel, brick, concrete—heavy manufacturing	43.5
Fireproof	2-story steel, brick printing plant—high-class construction	57.1
	Warehouse (including light and heat)	
Fireproof	5-story steel, brick concrete—chain grocery type	26.5
Fireproof	14-story steel, brick, concrete—2 basements, fair construction	37.0
	Loft (including light, heat, plumbing)	
Non-fireproof	4-story basement and mezzanine—steel, brick, wood, steam heat	30.9
Semi-fireproof	6-story—brick, stone, wood, heavy timber, 2 stores 1st floor, elevator, pipe coil heat front and rear	29.2
Fireproof	12-story basement and sub-basement, typical mid-Manhattan type—steel, brick	43.6

CONVERSION FACTORS FOR CUBIC-FOOT COST OF BUILDINGS *

Conversion factors for cities other than New York. Multiply cubic foot costs, p. 206, by factors below for costs in cities listed.

City and State	Conversion Factor %
Albany, N. Y.	88.9
Atlanta, Ga.	70.0
Atlantic City, N. J.	95.3
Baltimore, Md.	86.2
Binghamton, N. Y.	86.0
Birmingham, Ala.	79.0
Boston, Mass.	96.8
Bridgeport, Conn.	95.3
Buffalo, N. Y.	90.0
Burlington, Vt.	81.9
Charlotte, N. C.	61.7
Chattanooga, Tenn.	78.5
Chicago, Ill.	90.3
Cincinnati, Ohio	87.7
Cleveland, Ohio	93.3
Columbus, Ohio	87.5
Dallas, Texas	82.3
Dayton, Ohio	95.0
Denver, Colo.	84.8
Des Moines, Iowa	95.0
Detroit, Mich.	97.5
East Orange, N. J.	98.5
Elizabeth, N. J.	97.0
Elmira, N. Y.	91.0
Fall River, Mass.	93.1
Grand Rapids, Mich.	85.3
Hackensack, N. J.	96.5
Harrisburg, Pa.	72.5
Hartford, Conn.	85.0
Hempstead, L. I.	97.4
Houston, Texas	83.3
Indianapolis, Ind.	91.9
Jamestown, N. Y.	93.8
Jersey City, N. J.	98.4
Kansas City, Mo.	94.2
Lewiston, Maine	65.0
Los Angeles, Calif.	72.8
Louisville, Ky.	89.3
Lynn, Mass.	92.6
Manchester, N. Y.	76.0
Memphis, Tenn.	85.0
Miami, Fla.	81.4
Milwaukee, Wis.	88.3
Minneapolis, Minn.	90.4
Montreal, Canada	75.8
Newark, N. J.	98.5
New Bedford, Mass.	91.8
New Britain, Conn.	94.5
New Haven, Conn.	97.5
New London, Conn.	96.8
New Orleans, La.	85.1
New York, N. Y.	100.0
Newburgh, N. Y.	91.3
Oakland, Calif.	82.0
Omaha, Neb.	85.1
Passaic, N. J.	97.6
Paterson, N. J.	97.6
Pawtucket, R. I.	95.6
Philadelphia, Pa.	88.1
Pittsburgh, Pa.	99.7
Portland, Maine	71.5
Portland, Ore.	67.6
Providence, R. I.	97.3
Richmond, Va.	74.0
Rochester, N. Y.	93.4
San Francisco, Calif.	78.4
Seattle, Wash.	77.6
Springfield, Mass.	95.4
St. Louis, Mo.	90.7
Stamford, Conn.	94.7
Syracuse, N. Y.	95.2
Toledo, Ohio	96.4
Topeka, Kans.	89.0
Trenton, N. J.	95.6
Utica, N. Y.	93.4
Washington, D. C.	87.0
Watertown, N. Y.	93.3
Waterbury, Conn.	96.3
White Plains, N. Y.	96.8
Wichita, Kans.	81.4
Wilmington, Del.	82.3
Worcester, Mass.	92.0
Wyandotte, Mich.	89.8
Yonkers, N. Y.	90.4
Youngstown, Ohio	90.8

* From "The Dow Service Real Estate Valuation Calculator" (revised 1941).

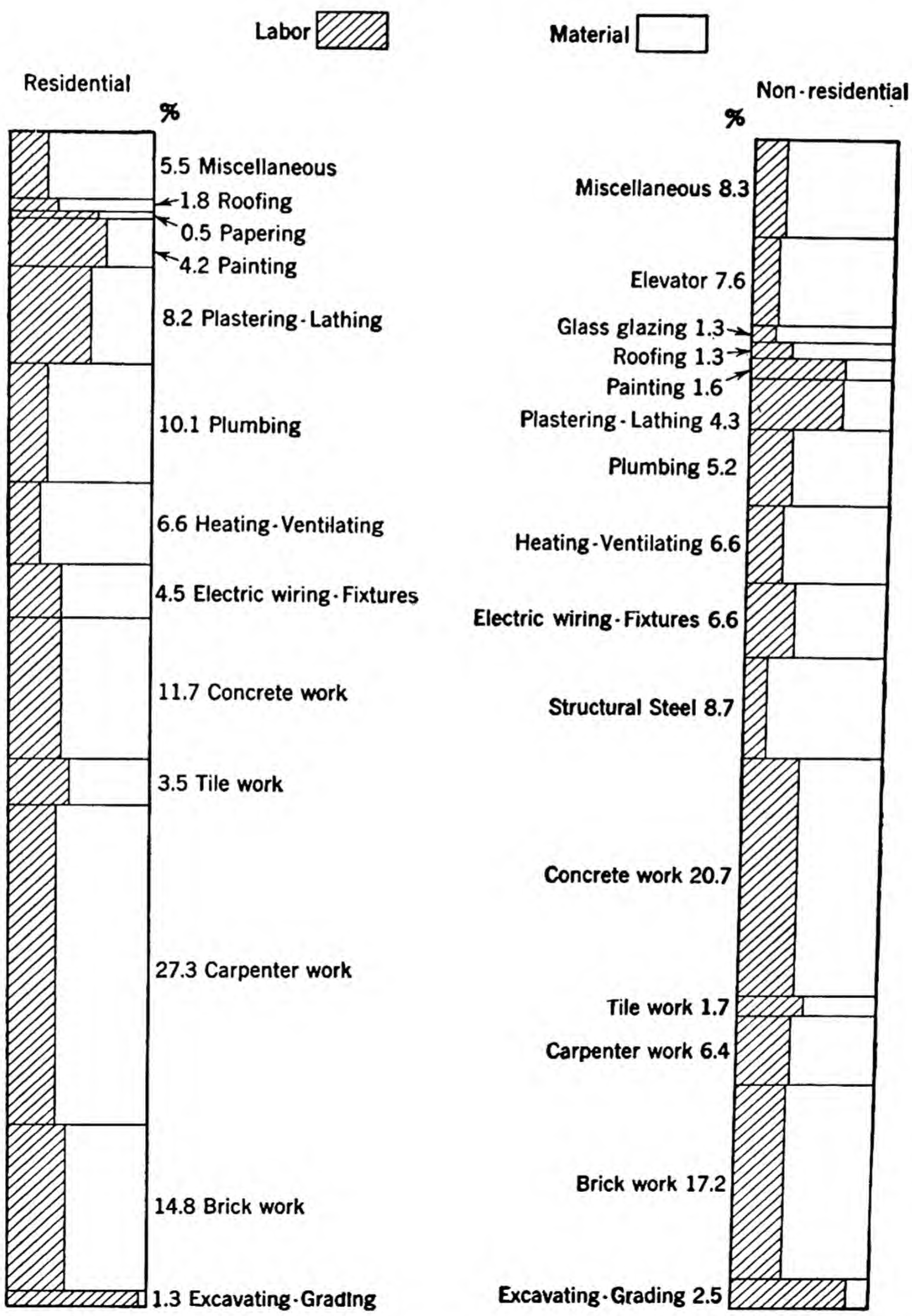
REAL ESTATE DEVELOPMENTS

Cost per acre, E.N.R. Construction Index 235.5.

Item	Cost in Dollars
Grading	250
Paving	1400
Water	500
Sewer	300
Drainage	200
Total	2650

Costs based on 3 lots per acre, streets 50 ft. right of way, and 24 ft. bituminous pavement, curbs, no sidewalks. Add for long water-supply mains, trunk sewers, access roads, and electric power where required.

PER CENT THAT COST OF EACH CLASS OF WORK FORMS OF TOTAL COST OF BUILDING IN REPRESENTATIVE CITIES *



* From U. S. Dept. of Labor.

ELEMENTS OF STRUCTURES

(All Costs in Dollars)

	Material	Labor	Total	Plant and Job Insurance Overhead and Profit	General Contractor Overhead and Profit	Date	Location
Concrete							
Plant mix per cu. yd.							
2000 lb. stone	6.65	....	....	....	....	1939	F.O.B. plant, N.Y.C.
3000 lb. stone	7.10	....	....	....	....	1939	
3750 lb. stone	7.60	....	....	....	....	1939	
1 : 2 : 5 cinder concrete per cu. yd.	5.35	....	....	....	....	1939	
Transportation under 4 mi., per cu. yd. per mi.	0.18	....	....	....	....	1939	N.Y.C. area
Transportation over 4 mi., per cu. yd. per mi.	0.12	....	....	....	....	1939	
Cement per bbl.	2.20	....	....	....	....	1939	F.O.B. job, N.Y.C. area
Sand per cu. yd.	1.25	....	....	....	....	1939	
Gravel or stone per cu. yd.	2.25	....	....	....	....	1939	
Concrete Forms per Sq. Ft. (3 uses of material)							
Slabs including uprights	....	....	0.18	Included	Add	1939	Middle Atlantic States
	....	....	0.27	Included	Add	1944	
Columns	....	....	0.24	Included	Add	1939	
	....	....	0.36	Included	Add	1944	
Beams sides and soffits	....	....	0.23	Included	Add	1939	
	....	....	0.35	Included	Add	1944	
Walls—Surfaces in contact	....	....	0.19	Included	Add	1939	
	....	....	0.28	Included	Add	1944	
Footing	....	....	0.18	Included	Add	1939	
	....	....	0.27	Included	Add	1944	
Extra for smooth surface (substitute for plaster)	....	....	0.04	Included	Add	1944	
Concrete Placing per Cu. Yd.							
Floors	....	2.90		Included	Add	1939	Middle Atlantic States
Walls	....	2.50		Included	Add	1939	
Footing	....	2.30		Included	Add	1939	
Concrete Retaining Walls (excavation not included) per Ft. of Length							
5 ft. high	....	....	20.00	Included	Add	Jan. 1945	N.Y.C. area
10 ft. high	....	....	45.00	Included	Add	Jan. 1945	
20 ft. high	....	....	110.00	Included	Add	Jan. 1945	
Curing Concrete Slabs per Sq. Yd.	....	....	0.02	Included	Add	1939	Middle Atlantic States
Excavation per Cu. Yd. (Add pumping, shoring disposal)							
Earth, machine	....	0.55	0.55	Included	Add	1939	Middle Atlantic States
Earth, hand	....	1.30	1.30	Included	Add	1939	
Unclassified	....	2.00	2.00	Included	Add	1939	
Shale or hardpan	....	2.00	2.00	Included	Add	1939	
Rock, soft	....	3.50	3.50	Included	Add	1939	
Rock, hard	....	5.50	5.50	Included	Add	1939	
Line-holing (per lin. ft.)	....	0.50	0.50	Included	Add	1939	
Flame Cutting per Sq. In. of Metal Cut	....	....	1.00	Included	Add	Jan. 1945	N.Y.C. area
Floor Finishes per Sq. Ft.							
Troweled concrete	....	....	0.04	Included	Add	Jan. 1945	N.Y.C. area
1 in. mortar	....	....	0.07	Included	Add	Jan. 1945	

ELEMENTS OF STRUCTURES (Continued)

	Material	Labor	Total	Plant and Job Insurance Overhead and Profit	General Contractor Overhead and Profit	Date	Location
Floor Finishes (Continued)							
Ceramic tile, standard patterns	....	....	1.00	Included	Add	Jan. 1945	N.Y.C. area
Terrazzo, ordinary divisions	....	....	1.40	Included	Add	Jan. 1945	
Rubber tile, regular colors and sizes	....	....	0.80	Included	Add	Jan. 1945	
Asphalt tile, regular colors and sizes	....	....	0.30	Included	Add	Jan. 1945	
Quarry tile, 6-in. squares	....	....	1.10	Included	Add	Jan. 1945	
Cork, regular colors and sizes	....	....	0.65	Included	Add	Jan. 1945	
Linoleum, $\frac{3}{16}$ in.	....	....	0.40	Included	Add	Jan. 1945	
Floor fill and sleepers	....	....	0.09		Add	1939	
Floor fill and sleepers	....	....	0.16		Add	1944	
Gunite per Sq. Ft.*							
First 1 in.	0.08	0.25	0.33	0.25	Add	1946	N.Y.C. area
Additional 1 in.	0.07	0.18	0.25	0.20	Add	1946	
Piles per Ft. (based on 500 at 40 ft. long)							
See also cost data under "Dock Work"							
Timber, 20 ton, untreated	....	....	0.70	Included	Add	1939	New England and Middle Atlantic States
Timber, 20 ton, treated	....	....	1.10	Included	Add	1939	
Concrete, 30 ton, precast	....	....	3.50	Included	Add	1939	
Concrete, 30 ton cast in place	....	....	2.00	Included	Add	1939	
Steel, 30 ton H columns	....	....	2.50	Included	Add	1939	
Open steel pipe							
55 ton, $10\frac{3}{4}$ in.	....	....	3.00	Included	Add	1939	
70 ton, $12\frac{3}{4}$ in.	....	....	3.75	Included	Add	1939	
90 ton, 15 in.	....	....	4.50	Included	Add	1939	
100 ton, 16 in.	....	....	5.00	Included	Add	1939	
120 ton, 18 in.	....	....	6.00	Included	Add	1939	
Roofing per 100 Sq. Ft.							
Plain slate	....	....	40.00	Included	Add	1944	N.Y.C. area
Heavy slate	....	....	65.00	Included	Add	1944	
Asbestos shingle	....	....	30.00	Included	Add	1944	
Asphalt shingle	....	....	11.00	Included	Add	1944	
Wood shingle	....	....	12.00	Included	Add	1944	
20 yr. bonded, flat	....	....	12.00	Included	Add	1944	
1 in. insulation under roofs	....	....	10.00	Included	Add	1944	
Sandblasting per Sq. Ft.							
Unpainted surfaces	....	....	0.07	Included	Add	1944	N.Y.C. area
Painted or waterproofed surfaces	....	....	0.12 to 0.15	Included	Add	1944	
Sheet Piling per Sq. Ft. (bracing included)							
Wood, 12 ft. deep excavation	....	....	0.60	Included	Add	1939	New England and Middle Atlantic States
Wood, 18 ft. deep excavation	....	....	0.85	Included	Add	1939	
Wood, 24 ft. deep excavation	....	....	1.50	Included	Add	1939	
Steel, 12 ft. deep excavation	....	....	1.25	Included	Add	1939	
Steel, 18 ft. deep excavation	....	....	1.75	Included	Add	1939	
Steel, 24 ft. deep excavation	....	....	2.50	Included	Add	1939	
Steel, Bar Joists per ton	98.00	26.00	124.00	Included	Add	1939	Middle Atlantic States
Steel, Reinforcing Bars per ton							
$\frac{3}{4}\phi$	51.00 †	46.00	108.00	Included	....	1939	N.Y.C. area

* Based on clean surfaces, ordinary scaffolding.
† Base price $\frac{3}{4}$ and larger; add per ton for $\frac{5}{8}\phi$, \$2.00; $\frac{1}{2}$, \$4.00; $\frac{3}{8}$, \$8.00; $\frac{1}{4}$, \$20.00.

ELEMENTS OF STRUCTURES (Continued)

	Material	Labor	Total	Plant and Job Insurance Overhead and Profit	General Contractor Overhead and Profit	Date	Location
Steel, Reinforcing Bars (Continued)							
Up to $\frac{1}{2}$ in. N.Y.C.	55.00 †	155.00 ‡	210.00	Included	Add	1944	N.Y.C. area
Placing $\frac{1}{2}$ in. to 1	55.00 †	140.00 ‡	195.00	Included	Add	1944	N.Y.C. area
1 in. and over	55.00 †	120.00 §	175.00	Included	Add	1944	N.Y.C. area
Steel, Reinforcing Mesh per Sq. Yd.							
4 in. by 16 in., #5 by #10	0.17	0.24	0.41	Included	Add	1939	N.Y.C. area
(1.4 lb./sq. ft.)	0.21	0.40	0.61	Included	Add	1944	N.Y.C. area
Steel, Structural per Ton							
Apartment, 12-story							
Live load 40 lb.							
12–15 lb./sq. ft.	....	....	100.00	Included	Add	1939	Middle Atlantic States
Hotel, 12-story							
14–18 lb./sq. ft.							
Live load 40 lb.	....	....	100.00	Included	Add	1939	Middle Atlantic States
Office building							
Low							
Live load 50 lb.							
18 lb./sq. ft.	....	....	100.00	Included	Add	1939	Middle Atlantic States
20-story, 20.5 lb./sq. ft.	....	....	93.00	Included	Add	1939	Middle Atlantic States
Over 35-story, 25 lb./sq. ft.	....	....	93.00	Included	Add	1939	Middle Atlantic States
Light manufacturing							
20-story 75 lb. live load	....	....	90.00	Included	Add	1939	Middle Atlantic States
19 lb./sq. ft.	....	....	90.00	Included	Add	1939	Middle Atlantic States
Loft, 16- to 20-story							
Live load 120 lb.	....	....	88.00	Included	Add	1939	Middle Atlantic States
20 lb./sq. ft.							
Trusses	....	....	130.00	Included	Add	1939	Middle Atlantic States
Plate girders	....	....	120.00	Included	Add	1939	Middle Atlantic States
Steel Sash per Sq. Ft.	....	....	1.00	Included	Add	1944	Middle Atlantic States
Timber per M.B.F.							
Floor Framing	48.00	52.00	100.00	Included	Add	1939	Middle Atlantic States
Trusses	53.00	132.00	185.00	Included	Add	1939	Middle Atlantic States
Welding, Field (shop welding 80% of costs given)							
Cost per ft. of weld							
$\frac{3}{16}$ Down	....	....	0.85	Included	Add	Jan. 1945	N.Y.C. area
$\frac{3}{16}$ Overhead	....	....	1.35	Included	Add	Jan. 1945	N.Y.C. area
$\frac{1}{4}$ Down	....	....	1.00	Included	Add	Jan. 1945	N.Y.C. area
$\frac{1}{4}$ Overhead	....	....	1.50	Included	Add	Jan. 1945	N.Y.C. area
$\frac{3}{8}$ Down	....	....	1.35	Included	Add	Jan. 1945	N.Y.C. area
$\frac{3}{8}$ Overhead	....	....	1.75	Included	Add	Jan. 1945	N.Y.C. area
Wrecking Inside Buildings per Cu. Yd.							
Mass concrete, not reinforced	....	....	5.50	Included	Add	Jan. 1945	N.Y.C. area
Mass concrete, reinforced			13.50	Included	Add	Jan. 1945	N.Y.C. area
Slabs on ground, not reinforced			4.00	Included	Add	Jan. 1945	N.Y.C. area
Slabs on ground, reinforced			6.50	Included	Add	Jan. 1945	N.Y.C. area
Slabs, unsupported			5.50	Included	Add	Jan. 1945	N.Y.C. area

† Base price $\frac{3}{4}$ and larger; add per ton for $\frac{5}{8}$ ϕ, \$2.00; $\frac{1}{2}$, \$4.00; $\frac{3}{8}$, \$8.00; $\frac{1}{4}$, \$20.00.
‡ Deduct 65.00 if no bending at job.
§ Deduct 45.00 if no bending at job.

PLYWOOD

Cost Control—1946

F.O.B. New York City. Costs are per square foot for exterior, sound one side plywood.*

Thickness	Cost
$\frac{1}{8}$ in.	8¢
$\frac{3}{16}$ in.	$8\frac{1}{2}$¢
$\frac{1}{4}$ in.	9¢
$\frac{3}{8}$ in.	11¢
$\frac{1}{2}$ in.	17¢
$\frac{5}{8}$ in.	20¢
$\frac{3}{4}$ in.	24¢

Forms

Thickness	Cost
$\frac{1}{2}$ in.	16¢
$\frac{5}{8}$ in.	18¢
$\frac{3}{4}$ in.	20¢

GLASS BLOCK MASONRY

Cost Control—1946

New York City. $2.25 per sq. ft.

SWIMMING POOLS

Cost Control—1945

Medium pool, 35 ft. by 75 ft. ±		
Structure		$ 6,500
Equipment:		
recirculating	550	
chlorinating	880	
filtering	3,850	5,280
Fittings (diving boards, ladders, etc.)		720
Total		$12,500
Small pool, 25 ft. by 60 ft. ±		$10,000
Large pool, 50 ft. by 100 ft. ±		$20,000

FLOOR SYSTEMS

The first column of Table I shows the 1939 basic costs per square foot of different types of floor systems constructed with fill and sleepers. For a stuck-down floor without fill or finish the costs should be changed as shown in column 8. In good practise, however, fill and finish are used, even in stuck-down floors, to reduce sound transmission and to increase stability.

The other columns in the table list factors to be taken into account in selecting the type of floor system desired. They show how the final cost of a system is not necessarily directly dependent on its initial cost. For instance, an expensive light-weight system may reduce the price of the supporting columns and girders; a beam-and-girder system is not usually economical if a flat ceiling is required; and with increasing live load, a reinforced-concrete system becomes more economical.

Beams and slabs and ribbed joists are to be preferred for long spans, and clay tile fillers for short ones.

It should be noted that the premanufactured systems, such as Gypsum plank and Dextone, are more suitable for the small builder, as they require very little plant or manufacturing skill in the field. For large jobs, on the other hand, where the work can be properly organized, more complicated systems are likely to be less expensive.

Table II shows the derivations of the prices in Table I by itemizing the material required for a particular floor panel on the following assumptions: floor panel, 20 by 25 ft.; live load, 60 lb.; stress in the steel, 20,000 lb.; bar joist stresses, in accordance with the specification of the Steel Joist Institute; semi-continuous conditions for those systems where continuity is utilized; no account taken for supporting beams and columns.

The unit costs cited are for the New England and Middle Atlantic areas.

The prices have been formulated with the following allowances:

Material	
Job overhead	4%
Profit	10%
Total	14%

Labor	
Insurance	15%
Job overhead	4%
Profit	10%
Total, cumulative, use	32%

* Costs are for material only and do not include labor.

TABLE I

Modifying Factors

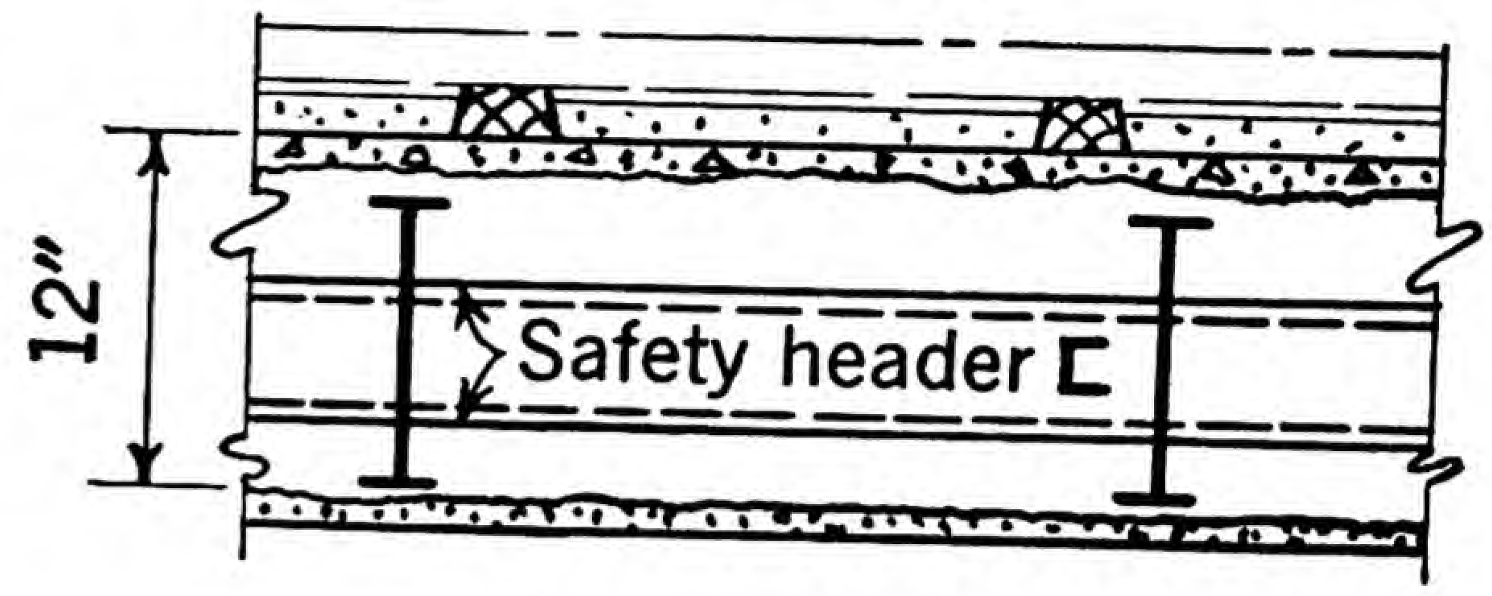
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
		Base Price per Square Foot (Cents)	Adaptability for Monolithic or Terrazzo Finish	Winter Construction	Insurance and Safety from Fire	Foolproof Construction	Effect on Supporting Structural Steel	Absence of Suitable Cinders	Base for Rubber Tile, Linoleum, and Stuck-down Wood *	Flat Ceiling Required	Ruggedness for Rolling or Concentrated Loads	Conduit Space Required	Sound Transmission	Permanency	Plaster Bond
1	Trussed joists	70.6	†	Fair	Handicapped	O.K.	Cr.	O.K.	Dr. 2¢	O.K.	Barred	O.K.	‡	Fair	O.K.
2	Metal tile	71.2	O.K.	Handicapped	O.K.	Inspection required	Basic	O.K.	Dr. 2¢	O.K.	Handicapped	O.K.	O.K.	O.K.	O.K.
3	Gypsum plank	76.4	†	O.K.	Handicapped	xx	Cr.	O.K.	Cr. 1¢	O.K.	Barred	O.K.	‡	Fair	O.K.
4	Light-weight concrete plank	76.4 x	†	O.K.	Handicapped	O.K.	Cr.	O.K.	Cr. 1¢	O.K.	Barred	O.K.	‡	Fair	O.K.
5	Reinforced concrete beam and slab	78.1 (75.1)x	O.K.	Handicapped	O.K.	Inspection required	Basic	O.K.	Cr. 4¢	Dr. 9¢	O.K.	O.K.	O.K.	O.K.	†
6	Steel and cinder concrete arches	74.5	O.K.	Fair	O.K.	O.K.	Basic	Dr.	Dr. 2¢	Dr. 9¢	O.K.	Fill required	O.K.	O.K.	Care required
6a 6b	Steel and stone concrete	77.8 70.6 x	O.K.	Fair Fair	O.K.	O.K.	Basic	O.K.	Cr. 4¢	Dr. 9¢	O.K.	Fill required	O.K.	O.K.	†
7	Open joist non-fireproof	36.1	No	O.K.	Barred	O.K.	Cr.	O.K.	Dr. 12¢	O.K.	Dr. 6¢	O.K.	Bad	Fair	O.K.
8	Nassau	67.3	O.K.	Handicapped	O.K.	Inspection required	Basic	O.K.	Dr. 2¢	O.K.	O.K.	Fill required	O.K.	O.K.	O.K.
9	Two-way tile—Schuster	75.1	O.K.	Handicapped	O.K.	Inspection required	Basic	O.K.	Dr. 2¢	O.K.	O.K.	Fill required	O.K.	O.K.	O.K.
10	Two-way slag-block, Republic	75.1 x	O.K.	Handicapped	O.K.	Inspection required	Basic	O.K.	Dr. 2¢	O.K.	O.K.	Fill required	O.K.	O.K.	O.K.
11	Aerocrete	77.0	O.K.	Handicapped	O.K.	Inspection required	Cr.	O.K.	Dr. 2¢	O.K.	Handicapped	O.K.	O.K.	O.K.	†
12	Gritcrete x	70.4	O.K.	Fair	O.K.	O.K.	Basic	O.K.	Dr. 2¢	Dr. 9¢	O.K.	Fill required	O.K.	O.K.	†
13	Precast Concrete I Beam (after Dextone)	69.0	†	O.K.	O.K.	O.K.	Basic	O.K.	Dr. 2¢	O.K.	Barred	Fill required	O.K.	O.K.	O.K.

* Basic price, column 1, credited with 9¢ for fill and sleepers omitted and debited with cost of a dusted or 1-in. monolithic finish or fill and finish as required.
† Not recommended.
‡ Floor fill essential.
x Plaster omitted.
xx Subject to damage during construction.

TABLE II

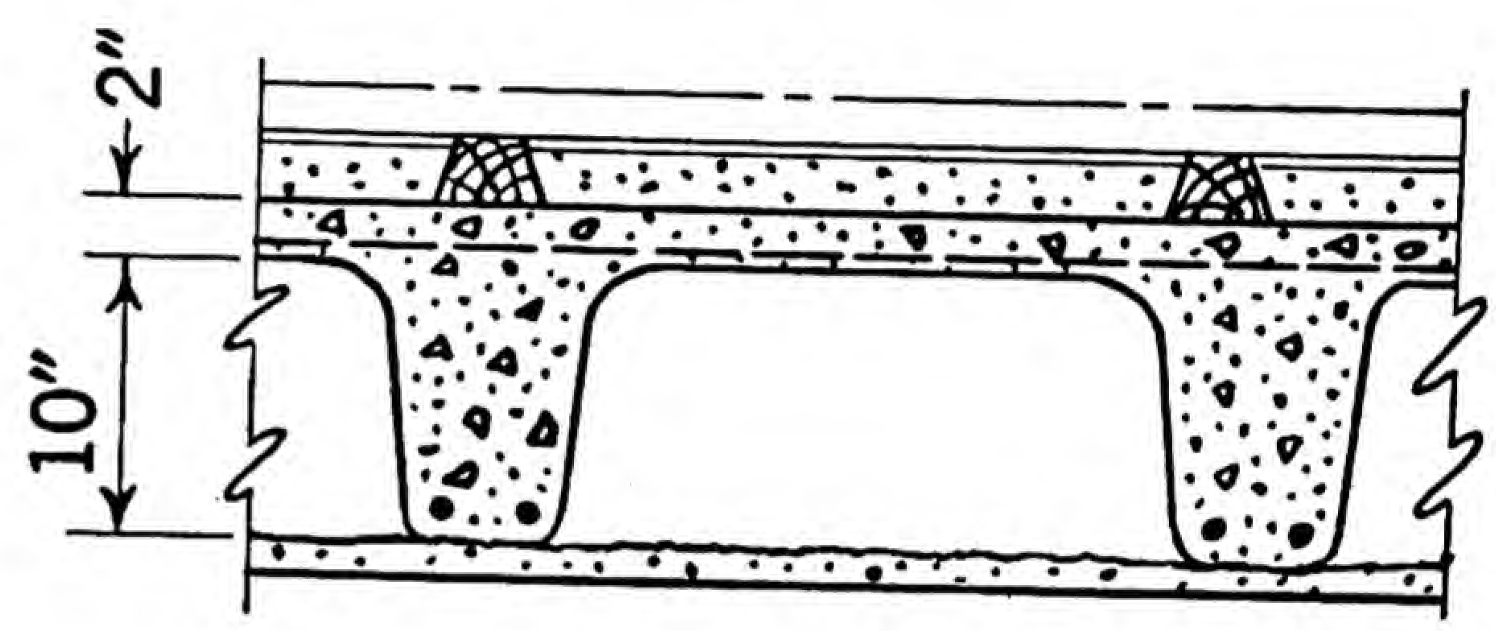
FLOOR-COST BREAKDOWNS

			1939	*1944*
1. Trussed Joists (1- to 2-hr. resistance)				
Joists, 4.3 lb./sq. ft.			26.8	30.1
Channel header, 0.40 lb./sq. ft.			2.4	2.7
Furring, 2 sq. ft.			12.0	14.8
Pencil rods, 0.30 lb./sq. ft.			1.8	2.2
2 in. stone concrete, 0.20 cu. ft./sq. ft.			7.6	8.9
Floor fill and sleepers			9.0	16.6
Plaster, 3 coats			10.0	14.5
Detail drawings			1.0	1.2
			70.6	91.0

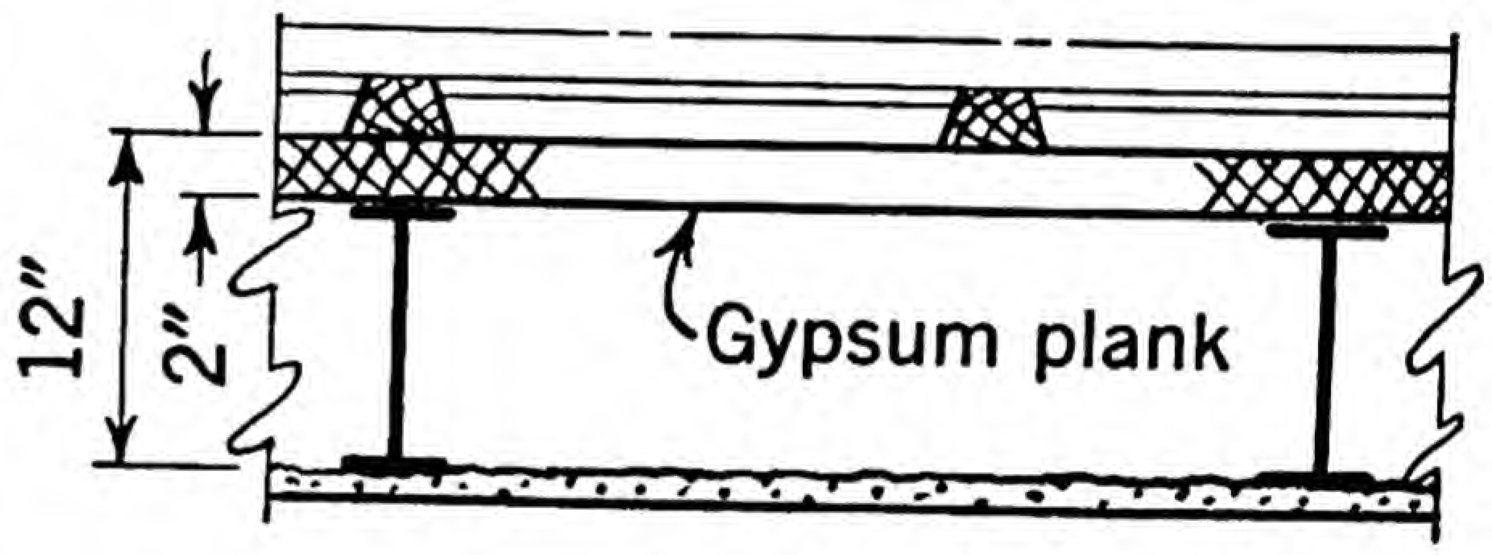


Jones & Laughlin junior sections comparable with steel joist.

2. Metal Tile (4-hr. resistance)				
Metal Tile,	6.0	7.4		
Forms,	12.0	20.4		
Total			18.0 *	27.8 *
Lath			6.0	7.4
Reinforcing steel, 2 lb./sq. ft.			11.0	14.6
Concrete, 0.40 cu. ft./sq. ft.			15.2	17.8
Floor fill and sleepers			9.0	16.6
Plaster, 3 coats			10.0	14.5
Detail drawings			2.0	2.4
			71.2	101.1

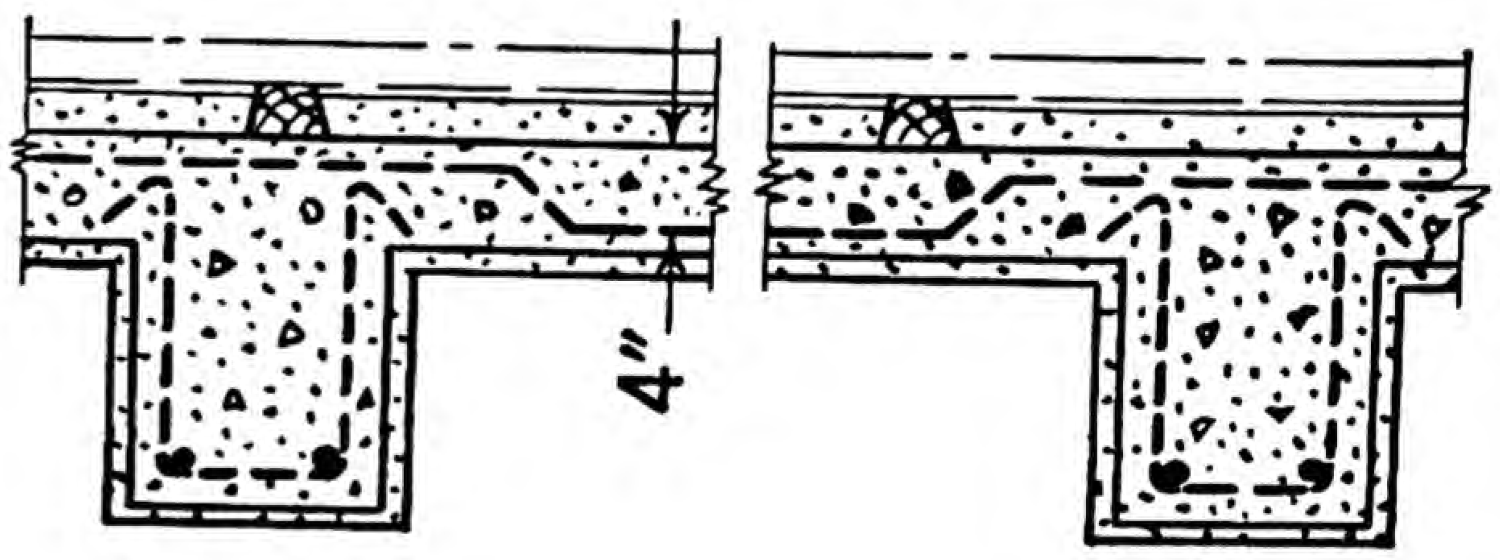


3. Gypsum Plank (1- to 2-hr. resistance)		
Bar Joist,† 4.0 lb./sq. ft.	25.0	28.0
Channel header, 0.40 lb./sq. ft.	2.4	2.7
Junior plank †	23.0	25.0
Furring	6.0	7.4
Floor fill and sleepers	9.0	16.6
Plaster, 3 coats	10.0	14.5
Detail drawings	1.0	1.2
	76.4	95.4



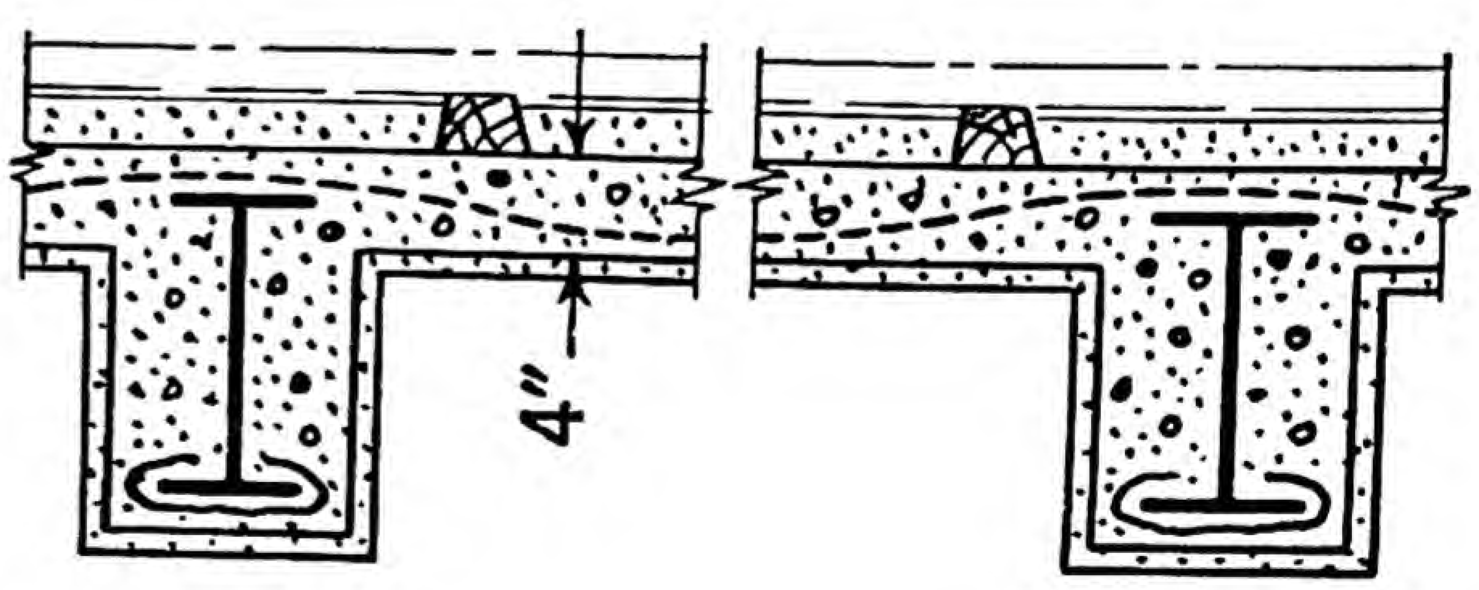
4. Light-Weight Concrete Plank, comparable with gypsum plank.

5. Reinforced-Concrete Beam and Slab (4-hr. resistance)		
Forms, 1 sq. ft., including beams	19.7	27.6
Reinforcing steel, 3.0 lb./sq. ft.	17.5	21.9
Stone concrete, 0.42 cu. ft./sq. ft.	16.0	18.7
Floor fill and sleepers	9.0	16.6
Plaster, bond and 2 coats, including beams	14.4	21.0
Detail drawings	1.5	1.8
	78.1	107.6



Note: If plywood forms are used and 3 coats of paint in place of plaster, subtract 5¢ from costs.

6. Steel and Cinder Concrete Arches (4-hr. resistance)		
Structural steel, 3.8 lb./sq. ft.	19.0	26.6
Forms, hung from steel, 1 sq. ft., including beams	16.0	23.0
Mesh, 1 sq. ft.	4.6	4.9
Cinder concrete, 0.42 cu. ft./sq. ft.	12.6	16.1
Floor fill and sleepers	9.0	16.6
Plaster, bond and 2 coats, including beams	13.3	19.3
	74.5	106.5



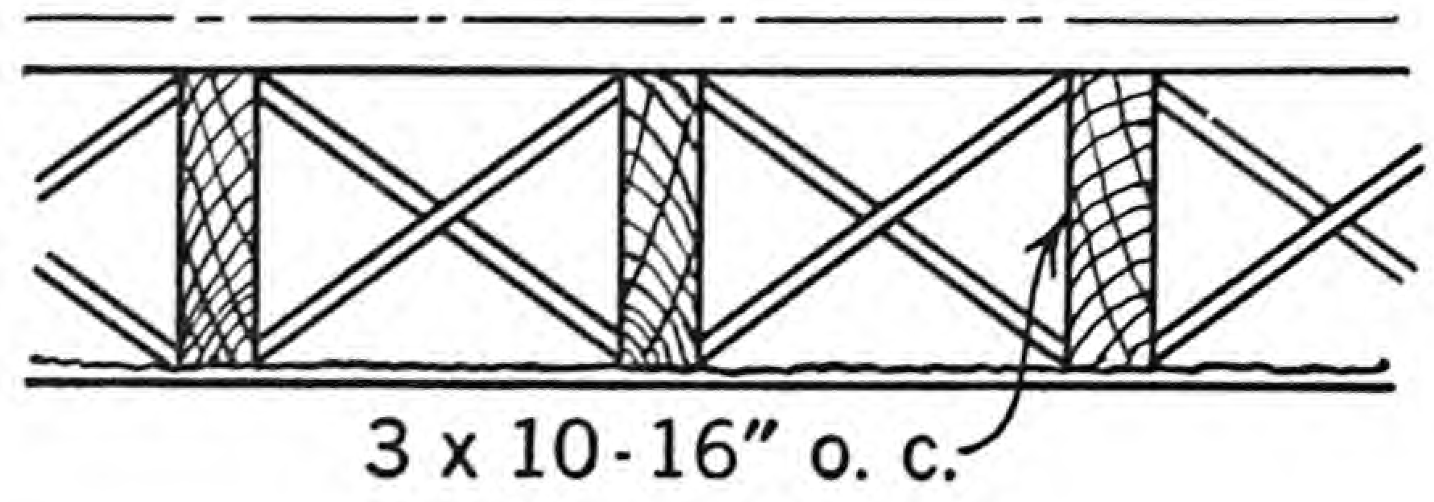
Notes. (*a*) If stone concrete is used in place of cinder concrete, add 3¢ to costs.

(*b*) If plaster is omitted and plywood forms, stone concrete, and 3 coats of paint are used, subtract 2¢ from costs.

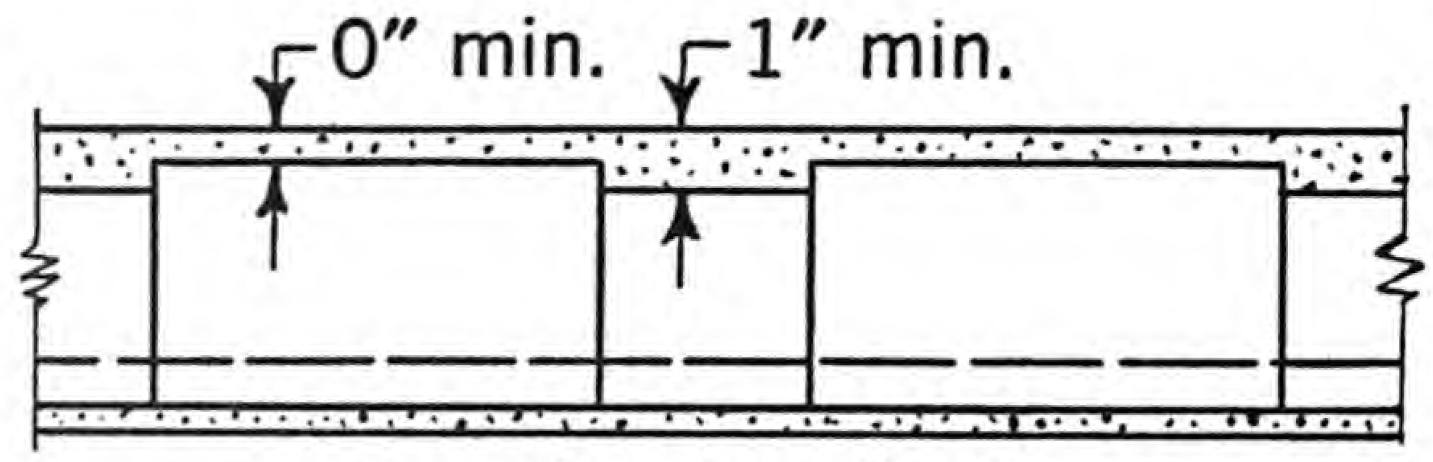
* Increase 5¢ if a small job. Decrease 3¢ for a large well-organized job where pans may be reused at least three times.
† Light structural members and senior plank may be substituted, but add furring angles and channels.

TABLE II (*Continued*)

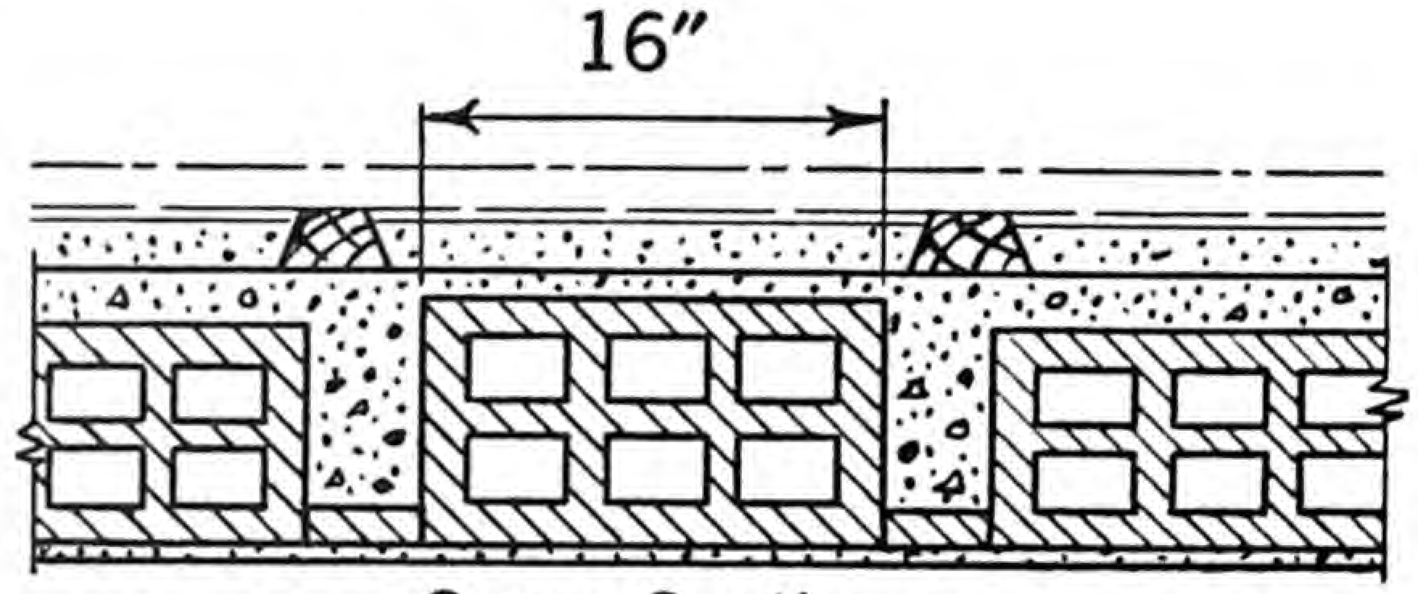
	1939	*1944*
7. Open Wood Joists (Non-Fireproof)		
Lumber, 2 f.b.m. per sq. ft. including joists and bridging	20.0	30.0
Lath	6.1	7.4
Plaster, 3 coats	10.0	14.5
	36.1	51.9



8. Nassau (4-hr. resistance)		
Forms, 1 sq. ft.	14.0	19.7
Tile, 8-in. tile	14.0	24.2
Soffit blocks	0.8	1.0
Reinforcing steel, 1.7 lb.	9.4	12.4
Concrete, 0.24 cu. ft.	9.1	10.7
Floor fill and sleepers	9.0	16.6
Plaster, 3 coats	10.0	14.5
Detail drawings	1.0	1.2
	67.3	100.3

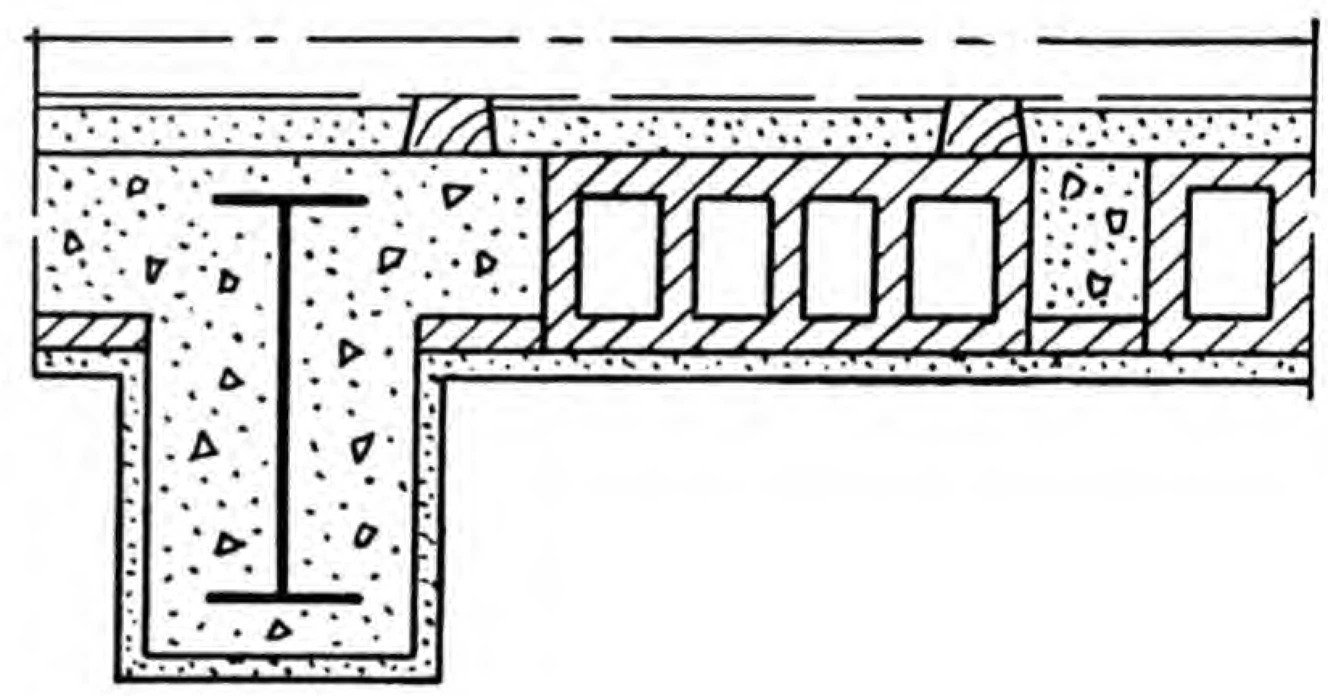


Longitudinal Section



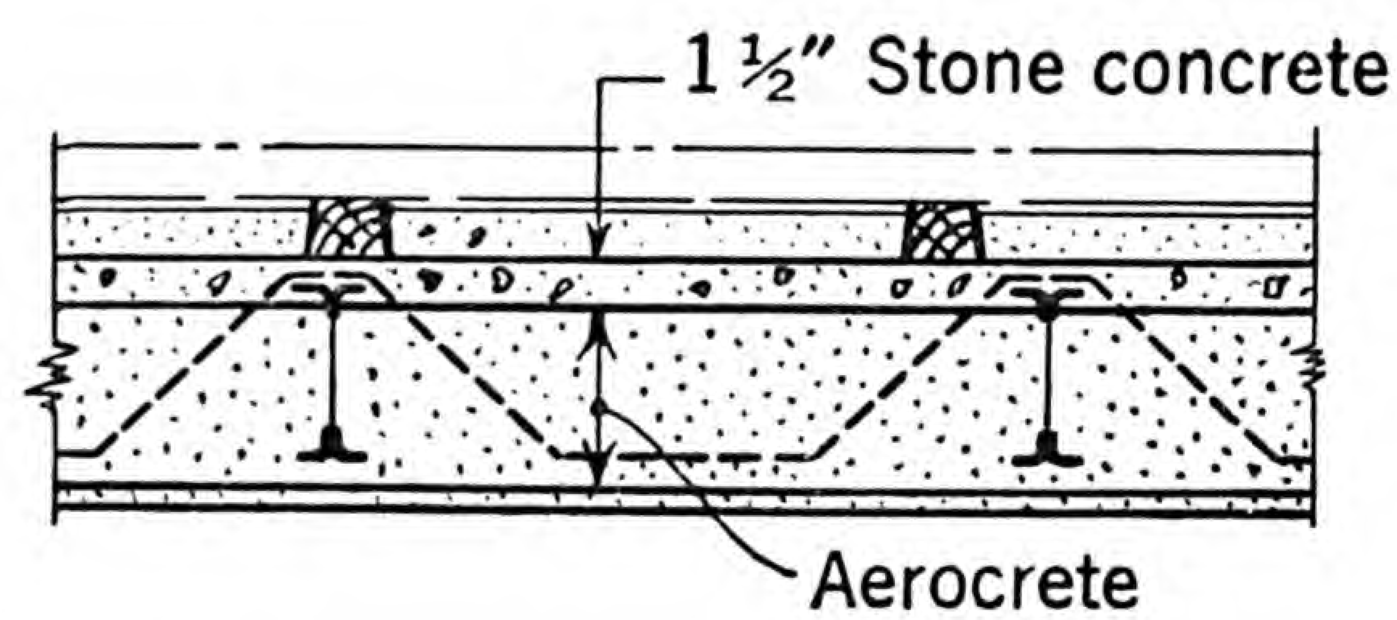
Cross Section

9. Schuster Two-Way System (4-hr. resistance)		
Steel for one side beam *	8.9	12.0
Forms	14.0	24.2
Tile, 1 sq. ft. 7 in.	11.0	13.2
Soffit blocks	1.6	2.0
Reinforcing steel, 2.3 lb. /sq. ft.	11.5	14.0
Concrete, 0.24 cu. ft. /sq. ft.	9.1	10.7
Fireproof I beam *	3.0	4.5
Floor fill and sleepers	9.0	16.6
Plaster, 3 coats, including beam	13.3	19.3
Detail drawings	1.0	1.2
	82.4	117.7
Credit for reduced height of building	3.0	4.0
	79.4	113.7



10. Republic (4-hr. resistance) comparable with Schuster two-way system

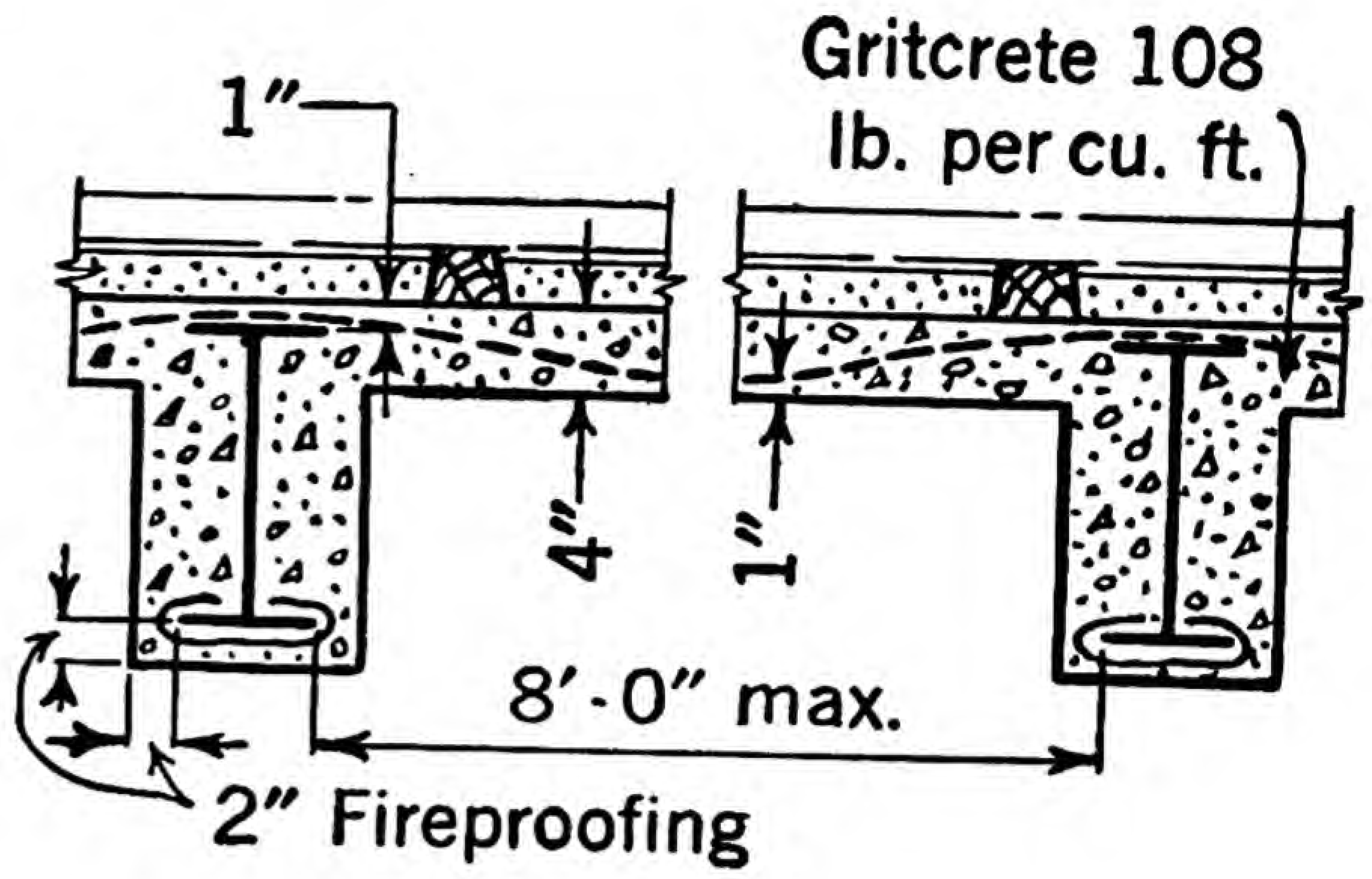
11. Aerocrete Reinforced Joist (4-hr. resistance)		
Steel joist, 4 lb. /sq. ft.	25.0	28.0
Forms, hung from steel	9.0	16.2
Reinforcing steel	3.5	4.3
Aerocrete, 0.5 cu. ft. /sq. ft.	15.5	17.9
Stone concrete, 0.21 cu. ft. /sq. ft.	8.0	9.3
Floor fill and sleepers	9.0	16.6
Plaster, 3 coats	10.0	14.5
	80.0	106.8
Credit for reduced height of building	3.0	4.0
	77.0	102.8



* Omit for skeleton design or 4-way bearing walls.

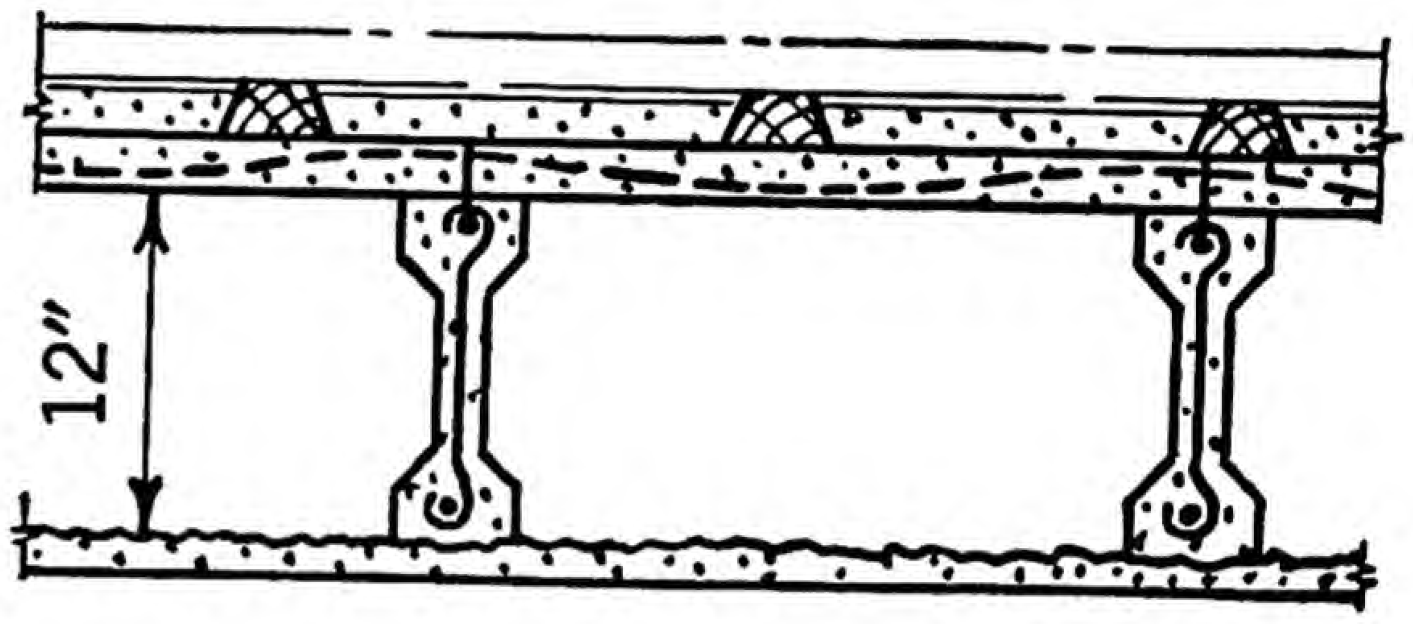
TABLE II (*Continued*)

	1939	*1944*
12. Gritcrete (aerocrete) (4-hr. resistance)		
Structural steel, 3.8 lb./sq. ft.	19.0	26.6
Forms, 1 sq. ft., including beams, plywood	20.0	27.0
Mesh, 1 sq. ft.	4.6	4.9
"Gritcrete," 0.42 cu. ft./sq. ft.	13.8	16.0
Floor fill and sleepers	9.0	16.6
Trimming and 3 coats of paint	4.0	9.0
	70.4	100.1



Note: If plaster is used instead of plywood forms and paint, add 5¢ to cost.

13. Precast Concrete I Beam (after Dextone)		
Concrete joist	20.0	22.6
Floor slabs	13.0	14.4
Erection, trucking †	10.0	18.0
Furring	6.0	7.4
Floor fill and sleepers	9.0	16.6
Plaster, 3 coats	10.0	14.5
Detail drawings	1.0	1.2
	69.0	94.7



† Subject to jurisdictional disputes.

ELEMENTS OF BUILDINGS—WALLS

Cost Control: E.N.R. Building Index 197.4 for 1939. All costs are in dollars for items complete in place, including job overhead and profit but not general contractor's overhead and profit, for New England and Middle Atlantic areas. Unit material costs—face brick, $30.00 per M; rubble stone for facing, $7.00 per cu. yd.; rubble stone for foundation, $2.40 per cu. yd.; cut stone, $2.50 per cu. ft. Cost of furring, flashing, weatherproofing, etc., to be added to cost of brick, block, stone, and concrete walls as required.

BRICK, CINDER BLOCK, AND TERRA COTTA

16-in. solid brick	1.16 per sq. ft.	12-in. load-bearing block or terra cotta	0.47 per sq. ft.
12-in. solid brick	0.96 per sq. ft.	8-in. load-bearing block or terra cotta	0.42 per sq. ft.
8-in. solid brick	0.72 per sq. ft.	8-in. light-weight block or terra cotta	0.34 per sq. ft.
4-in. face brick plus 8-in. backup	0.88 per sq. ft.		

RUBBLE AND CUT STONE

18-in. rubble foundation	0.56 per sq. ft.	16-in. cut stone faced, 4 in. and 8 in. thick stone, brick backup	2.05 per sq. ft.
16-in. rubble superstructure	1.07 per sq. ft.	12-in. cut stone faced, 4-in. and 8-in. thick stone, brick backup	1.95 per sq. ft.
16-in. rubble faced plus brick backup	1.01 per sq. ft.		
16-in. ashlar-faced rubble	1.21 per sq. ft.		
12-in. rubble faced plus brick backup	0.91 per sq. ft.		

CONCRETE

$\frac{1}{2}$ Lb. Reinforcement per Sq. Ft. Both Surfaces

16 in. 0.88 per sq. ft. 12 in. 0.76 per sq. ft. 8 in. 0.63 per sq. ft.

VENEERS

Including Studwall with Sheathing and Building Paper

4-in. face brick	0.70 per sq. ft.	Clapboard (including paint)	0.34 per sq. ft.
Rubble stone	0.90 per sq. ft.		

INTERIOR PARTITIONS

3-in. gypsum (including plaster)	0.31$\frac{1}{2}$ per sq. ft.	2-in. cement plaster	0.25 per sq. ft.
3-in. terra cotta (including plaster)	0.34$\frac{1}{2}$ per sq. ft.	2-in. by 4-in. stud (including plaster)	0.31 per sq. ft.

PAINTING

Costs per Square Foot for One Coat

Wood 0.020 Steel 0.025 Plaster 0.035 Concrete 0.035. Add 70% for each additional coat.

MISCELLANEOUS

Flashing		**Weatherproofing**	
16-oz. copper	0.75 per sq. ft.	Asphalt, 2 coat	0.02 per sq. ft.
Copper-covered membrane	0.30 per sq. ft.	Parging face brick	0.03$\frac{1}{2}$ per sq. ft.
Membrane	0.15 per sq. ft.	Troweled mastic	0.04$\frac{1}{2}$ per sq. ft.
Lath or Surface for Plaster		**Plaster only (no lath)**	
Metal lath on wood furring	0.10 per sq. ft.	3 coats	0.90 per sq. yd.
Bracket metal furring	0.13 per sq. ft.	**Stucco only (no lath)**	0.18 per sq. ft.
3-in. free-standing tile	0.20 per sq. ft.	**Gutter, Copper 6 in.**	1.15 per lin. ft.
Split tile	0.15 per sq. ft.	**Leader, Copper 4 in. by 6 in.**	1.35 per lin. ft.
Wood or metal lath	0.06 per sq. ft.		

DOCK WORK *

E.N.R. Construction Index 294.5.

Cost Control: All costs for items complete in place for New England and Middle Atlantic States.

Timber Pier: $4.00 to $8.00 per sq. ft. Varies with length of piles, use of treated or untreated timber, live load, and usage.

Pier Sheds: $0.15 to $0.25 per cu. ft.

Quays: 40 ft. wide, on piles, with relieving platforms, $400.00 per lin. ft.

Groins: $35.00 per ft.

ELEMENTS OF DOCK WORK

	Material	Labor	Total	Plant and Job Insurance Overhead and Profit	General Contractor Overhead and Profit	Date	Location
Timberwork per M ft., b.m.							
LLYP, merchantable	108						
fastenings	20						
	128	50	178	Add 15% to 20%	Add	1944	Middle Atlantic States
SLYP, structural	83						
fastenings	20						
	103	50	153	Add 15% to 20%	Add	1944	
Timber shoring per M ft., b.m.	....	....	120	Add 15% to 20%	Add	1939	
Piles per lin. ft.	....	....	....	Add 15% to 20%	....	1944	
Douglas fir	....	....	....	....	....	1944	
or yellow pine	....	....	....	....	....	1944	
Up to 60 ft.	0.40	....	....	....	....	1944	
60 ft. to 75 ft.	0.50	....	....	....	....	1944	
Over 75 ft.	0.65	....	....	....	....	1944	
Creosoting	0.30	....	....	....	....	1944	
Soft driving	....	0.15	....	....	....	1944	
Stiff driving	....	0.30	....	....	....	1944	
Jetting	....	0.30	....	....	....	1944	
Regulating	....	0.05	....	....	....	1944	
Groins							
Creosoted timber piles (2290 ft.) per ft.	....	....	1.90	Included	Included	1943	Rehobeth Beach, Del.
Creo. timber wales (5.4 M ft.) per M ft., b.m.	....	....	200.00	Included	Included	1943	
Timber sheet piles (1.5 M ft.) per M ft., b.m.	....	....	180.00	Included	Included	1943	
Steel sheet piles (50-ton) per ton	....	....	100.00	Included	Included	1943	
Riprap per Cu. Yd. See note.							
Dumped	....	....	4.00	Included	Included	1944	New England and Middle Atlantic States
Hand-placed	....	....	12.00	Included	Included	1944	

Note: Cost of riprap varies widely, depending on cost of rock excavation and haul.

* See also data under "Elements of Structures."

RAILROADS

Cost Control: E.N.R. Construction Index 294.5 for 1943.

Cost of ties, rail, and other track materials are for materials only, F.O.B. site for Middle Atlantic and New England States. Cost of ballast is for material only, delivered in New York City area. Cost of track laying and surfacing is labor cost in New York City area. Cost of turnouts, slip switches, track per foot and accessories is for items complete in place in New York City area.

Track. (Cost per linear foot complete in place.)

Material	Main-Line Track 112-lb. Rail All New Material	Siding Track 90-lb. to 105-lb. Rail Relayer Rail
	Cost per ft.	Cost per ft.
Ties	$1.40	$1.00
Rail	1.47	0.70
Other track material	0.67	0.51
Ballast	1.76	1.29
Labor	2.20	2.00
Total	$7.50	$5.50

Accessories. (Complete in place.)

Derails	$100.00 each
Bumpers (heavy-duty)	120.00 each
Car stops	40.00 per set
Crossing pavement	0.60 per sq. ft.
Crossing planking	0.50 per sq. ft.
R.O.W. fence (rural)	0.30 per lin. ft.
R.O.W. fence (urban)	2.00 per lin. ft.
Snow fences	1.75 per lin. ft.

Main-Line Turnouts. (Complete in place.) New No. 8, $1,600.00; new No. 10, $1,750.00.

Siding Turnouts. (Complete in place.) Relayer material, $1000.00 each.

Slip Switches. (Complete in place.) New single, $5000.00; new double, $5500.00.

Ties. (Material only.)

Untreated 7″ x 9″ x 8′-6″	$1.80 each;	6″ x 8″ x 8′ 6″ $1.40 each
Treated 7″ x 9″ x 8′-6″	$2.30 each;	6″ x 8″ x 8′ 6″ $1.90 each
Bracket ties	$3.65 each	
Switch timber	$62.00 per M b.f.	

Rail. (Material only.) New, $44.00 per gross ton (2240 lb.). Relayer rail, $25.00 per gross ton.

Guard rail for bridges, etc., $15.00 per gross ton.

Other Track Material. (Material only.) Cost includes 6% for storage.

Angle bars for 100-lb. rail, $3.00 per pair. Bolts and washers, $0.11 each. Spikes $0.028 each. Tie plates for 100-lb. rail $0.31 each. Anticreepers, $0.22 each. Turnout and switch material, see complete costs above.

Ballast. (Material only.) Stone, $2.00 per cu. yd. Cinders, $0.70 per cu. yd. Slag, $0.50 per cu. yd. Gravel, $1.25 per cu. yd.

Track Laying and Surfacing. (Labor only.)

Laying track: 112-lb. rail, $2.20 per lin. ft.; 105-lb. rail, $2.10 per lin. ft.

Placing ballast, stone, gravel, $0.33 per cu. yd.; cinders, slag, $0.27 per cu. yd.

Siding Track. (Complete in place using 12-in. cinder ballast.) $4.75 per lin. ft.

TENNIS COURTS

Cost Control—1944

Clay court including fittings and fencing, $1500 to $2500.
Add for bituminous surface, $0.60 per sq. yd.
Add for concrete surface, $2.00 per sq. yd.

Heavy-Duty Ornamental Highway Bridges. E.N.R. Construction Index 235.51. **$6.00 to $10.00 per sq. ft.;** varies with architectural treatment, size of abutments, and foundations.

Concrete Rigid-Frame Bridges,* H 20 loading, cubic yards of concrete required per foot of width.
Note: Figure clear spans before using table. Interpolate between clear spans in table.
Use of table: Given, bridge length = 70 ft. ±.
Concrete required for single span (70 ft. ± clear span) = 16.2 cu. yd. per foot of width.
Concrete required for double span (intermediate support, 35 ft. ± clear span) = 8.3 cu. yd. per ft. of width.

	Clear Span										
No. of Spans	30	35	40	45	50	55	60	65	70	75	80
Single	5.5	6.6	7.7	8.9	10.3	11.7	13.0	13.6	16.2	18.0	19.4
Double	6.8	8.3	10.0	11.8	13.8	15.9	18.2	20.6	23.2	26.0	28.8

Reinforcement = approximately 110 lb. per cu. yd.

Steel Rigid-Frame Bridges.*

Quantities of Steel and Concrete Required

Interpolate between spans given.

Clear span between legs, ft.	80	90	100	110	120
Steel, lb. per ft. of width	5600	6630	7700	8835	10,090
Concrete, cu. yd. per ft. of width for floor, backslab, and encasement of vertical legs only	6.9	7.2	7.6	8.0	8.3

Girders and floor beams spaced 11′–0″ o.c. Cost of footings, approach retaining walls, etc., not included.

Timber Bridges.†

Cost per Square Foot

Loading	Location	Year Built	Total Length in Feet	Cost per Square Foot	Loading	Location	Year Built	Total Length in Feet	Cost per Square Foot
H10	Ark.	1935	77	$0.88	H15	Kan.	1937	533	$1.39
H10	Kan.	1937	461	0.92	H15	Ala.	1924	665	1.55
H10	Ark.	1928	325	1.15	H15	Iowa	1937	138	2.01
H10	Ark.	1929	495	1.26	H15	Ohio	1932	120	2.22 ‡
H10	Ala.	1937	442	1.35	H15	Ala.	1924	714	2.98
H10	Del.	1936	13	2.25	H15	Ohio	1932	50	3.51 §
H10	Del.	1937	21	2.31	H15	N. J.	1936	45	3.82
H10	Del.	1937	33	2.40	H20	S. C.	1934	176	1.72
H10	Ala.	1922	96	2.57	H20	S. C.	1926	168	1.87
H10	Del.	1938	19	2.75	H20	S. C.	1925	84	2.06
H15	Okla.	1937	1151	1.29					

Miscellaneous. E.N.R. Construction Index 294.5. *See also "Road Costs."*

Cost of concrete in concrete rigid frames, $25–$50 per cu. yd.
Ashlar facing, $3.00 per sq. ft. of face.
Concrete railing, $3.00 to $5.00 per lin. ft.
4-in. pipe railing, $2.00 to $4.00 per lin. ft.
Floor drains, C.I., $20.00 each.
Blast plates, transite, $1.50 per sq. ft.

* From Arthur G. Hayden.
† Adapted from the Koppers Company.
‡ Steel stringers, 3 spans.
§ Steel stringers, 1 span.

Roads. Costs given in dollars per mile for two-lane roads; 100-ft. right-of-way cost not included in any cost per mile. E.N.R. Construction Index 294.5.

Type of Surface	No Base Light Grading *	6-in. Base Medium Grading *	12-in. Base Heavy Grading *
Bituminous surface treatment †	4,500	.....	.....
Sand clay, untreated	7,000	13,400	22,000
Stabilized soil	8,500	14,900	23,000
Gravel, untreated	10,000	16,400	25,000
Low-cost Bituminous mixtures	12,000	18,400	27,000
Macadam, untreated	15,000	24,000	37,000
Bituminous macadam	25,000	37,700	54,100
Bituminous concrete	30,000	42,700	59,100
Cement concrete	35,000	47,700	64,100
Brick	45,000	57,700	74,100
Granite block	75,000	87,000	104,000

† Costs are for treatment only of existing roads or surfaces.

Airports. Costs given in dollars per 100 lin. ft. of paved runway. E.N.R. Construction Index 294.5.

Wheel Load	No Base Light Grading *	6-in. Base Medium Grading *	12-in. Base Heavy Grading *
15,000 lb.	4,500	6,000	9,700
37,000 lb.	8,000	10,100	13,200
60,000 lb.	9,500	11,600	14,700

Cost includes taxiways, aprons, 150-ft. width of runway, 175 ft. of shoulder each side of which 75 ft. has selected fill and is turfed.

Cost of buildings, hangars, utilities, lighting, land not included.

* *Grading*

Light	1 ft. 2 in. average depth.
Medium	2 ft. 6 in. average depth.
Heavy	4 ft. 6 in. average depth.

Road Maintenance.* Cost in dollars per year for mile of 20-ft. width. Average for United States, 1931.

Type of Road	Cost	Type of Road	Cost	Type of Road	Cost
Surface treated	250 to 450	Bit. Road Mixes	200 to 350	Bit. Concrete	100 to 200
Sand clay, untreated	300 to 600	Water-Bound Macadam Untreated	500 to 750	Cement Concrete	75 to 150
Gravel untreated	450 to 700	Bituminous Macadam	150 to 300	Brick	100 to 200

* From "Highway Design and Construction" by A. G. Bruce, by permission of the International Textbook Company, Scranton, Pa.

Hangars. Complete with light, heat and plumbing, including repair shop and office—$6.00 to $12.00 per sq. ft., depending on contents and type of construction. Cost control—1946.

Paving and Miscellaneous

Cost Control. E.N.R. Construction Index 294.5. Costs include item complete in place and are average for Middle Atlantic and New England States.

Paving and Base Courses

			Cost per Square Yard
Crushed stone or selected gravel base per 1-in. depth			$0.10
Double bituminous surface treatment			0.30
Soil stabilization (6 in. of soil mixed with binder and/or calcium chloride)			0.75
Soil stabilization (6 in. of soil scientifically mixed with cement or bitumen)			0.85
Untreated macadam (water- or dry-bound) 6 in. deep			1.20
Mix in place, $2\frac{1}{2}$ in. imported material compacted	$0.65		
6 in. stone or gravel base, imported	0.60	Total	1.25
$2\frac{1}{2}$ in. low-cost plant mix including sand asphalt	0.65		
6 in. stone or gravel base, imported	0.60	Total	1.25
3 in. bituminous penetration macadam	0.90		
6 in. stone or gravel base, imported	0.60	Total	1.50
$1\frac{1}{2}$ in. natural rock asphalt (Midwest States)	0.70		
6 in. water-bound macadam base	1.20	Total	1.90
Bituminous concrete surface or binder course at 1 in. thick			0.50
Sheet asphalt surface course at $1\frac{1}{2}$ in. thick			1.10
Cement concrete base non-reinforced at 6 in. deep			1.25
Cement concrete pavement, non-reinforced at 7 in. deep			2.75
Cement concrete pavement, reinforced at 7 in. deep			3.00
Brick pavement including 6-in. deep non-reinforced concrete base			4.75
Granite block pavement, including 6-in. deep non-reinforced concrete base			6.50

Guard Rails

Light duty (wood posts and plank)	$0.50 per lin. ft.	Rustic log	$0.85 per lin. ft.
Heavy duty (cable)	0.60 per lin. ft.	Masonry walls	0.75 per lin. ft.
Heavy duty (plate)	2.00 per lin. ft.	Wood posts only	1.50 each

Miscellaneous

Curbs (steel)	$3.00 per lin. ft.	Cribbing (log)	$ 1.00 per sq. ft. of face
Curbs (stone)	3.25 per lin. ft.	Cribbing (concrete)	1.50 per sq. ft. of face
Curbs (concrete)	1.30 per lin. ft.	Cement rubble masonry	25.00 per cu. yd.
Sidewalks (4 in. concrete)	0.25 per sq. ft.	Underdrains, 6 in.	1.50 per lin. ft.
Sodding	0.35 per sq. yd.	3-ft.-wide concrete gutters 6 in. deep	1.35 per lin. ft.
Topsoiling 1 in. deep	0.06 per sq. yd.	Trimming shoulders and slopes	0.15 per lin. ft. of road
Seeding (machine)	0.01 per sq. yd.	Breakup and dispose concrete pavement	0.75 per sq. yd.
		Tie-down anchors, cement concrete pavement	2.00 each

EARTH MOVEMENT

Cost Control. E.N.R. Construction Index 294.5. All costs for Middle Atlantic and New England States Cost of equipment per 8-hr. day includes operator, fuel, depreciation, overhead, profit, minor delays, etc.

SOIL SURVEYS

Sounding rod (machine driven)	\$0.50 per ft.
Augur holes	1.00 per ft.
Wash borings	2.20 per ft.
Undisturbed earth samples ($2\frac{1}{2}$-in. casing)	1.00 each
Rock borings, $1\frac{3}{8}$-in. core	3.25 per ft.

SOIL TESTS—COST PER SAMPLE

"A" classification of soils	\$35.00
California bearing ratio—complete	35.00
Field load bearing test (exclusive of rental of 2 trucks and 1 crane)	200.00
Atterberg limits	4.00
Expansion characteristics	5.00
Shear strengths (including securing undisturbed samples)	100.00
Permeability, drainage	10.00
Moisture density relation	15.00
Mechanical analysis, sieve and hydrometer	12.00

CLEARING AND GRUBBING

1 to 5 acres	\$200 per acre
5 to 50 acres	150 per acre
Over 50 acres	100 per acre

Notes: Costs are based on average conditions. Work performed in swamps, mountainous country, heavily forested areas, or mainly by hand will increase costs.

TOPSOILING

6 in. stripped and piled, 0.75 per cu. yd.; furnished and spread, 6 in. 0.60 per sq. yd.

GRADING

Equipment	Cost of Equipment per Day	Cost
Rough grading, bulldozer:		
Small	\$46.00	\$0.05 per cu. yd.
Large	64.00	0.05 per cu. yd.
Rough grading, 10-ton motor grader	76.00	0.015 per sq. yd.
Fine grading, 10-ton motor grader	76.00	0.03 per sq. yd.
Fine grading, hand	10.80	0.07 per sq. yd.

ROLLING

Equipment	Cost of Equipment per Day	Cost per Sq. Yd.
Sheep's-foot, double drum	\$70.80	\$0.007
Rough grading, 3 wheel, 10 ton	43.20	0.009
Fine grading, 3 wheel, 10 ton	43.20	0.018
Water truck	35.00	0.0035

Notes: Add for cost of transportation of equipment to and from site.
Depth of fill for grading and rolling assumed 8 in. Cost of 2 laborers included in cost of equipment per day for bulldozer and motor-grader operations.

EXCAVATION, GENERAL *

COST PER CUBIC YARD. SHEETING OR PUMPING NOT INCLUDED

Material	Trench † Dry	Trench † Wet	Foundations † Dry	Foundations † Wet	Heavy Construction ‡ Airports, Roads, Reservoirs, etc.	Cofferdams §
Sand	\$ 0.65	\$1.35	\$1.35	\$2.65	\$0.60	\$2.65
Gravel	0.95	2.00	1.70	3.35	0.65	3.35
Clay	1.35	2.65	2.00	2.65	0.95	4.00
Shale	4.50		4.00		3.00	
Hardpan	6.70	13.50	5.35	8.00	2.65	8.00
Limestone	8.00		4.50		3.50	
Gneiss	12.00		7.00		4.50	
Granite or trap	13.50		8.00		5.00	

* From Tuller Construction Co.
† Not over 10 ft. deep.
‡ Not over 20 ft. deep.
§ Costs include 1-mile haul. Additional haul. 15¢ per ton-mile.

EARTH EXCAVATION

Method	Size of Equipment	Cost of Equipment 8-hr. Day	Cost per Cu. Yd. Ordinary Operation	Cost per Cu. Yd. Difficult Operation
Hand	......	$ 8.00	$1.00	$2.00
Clamshell	1 yd. bucket	120.00	0.40	0.70
Dragline	$1\frac{3}{4}$ yd. bucket	150.00	0.15	0.22
Power shovel	$1\frac{1}{2}$ yd. bucket	150.00	0.10	0.15
Back hoe	1 cu. yd.	100.00	0.45	0.60
Trenching machine	Medium	75.00	0.25	0.35
Conveyor-type loading machines	48-in.	165.00	0.07	0.13
Hydraulic dredges	27-in. discharge	3700.00 *	0.12 *	0.38 *

* Based on 24-hr. day.

Notes: Cost of dredges includes all pipe required to place fill where desired.

All costs based on continuous removal of excavated material.

Sheathing—pumping not included.

Add for cost of transportation of equipment to site.

Costs do not include trucking of materials away from equipment.

12 CU. YD. SCRAPER OPERATION

Cost of equipment per 8-hr. day = $150.00.

Length of haul, ft.	200	300	400	500	600	800	1000	1200	1400	1600	1800	2000
Cost per cu. yd.	$0.19	0.21	0.24	0.27	0.30	0.34	0.38	0.42	0.47	0.52	0.58	0.65

Note: Add for seasonal delays according to nature of material to be moved. Add $450 for average transportation cost of each scraper to and from site.

5 CU. YD. DUMP TRUCK OPERATION

Cost of equipment per 8-hr. day = $29.20.

Costs in table do not include cost of loading truck, which can be taken from Table above, headed "Earth Excavation." Cost of dump-truck operation can be applied to stone, gravel, or sand.

Length of haul, miles	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$	1	2	3	4	5	$7\frac{1}{2}$	10	15	20
Rough dirt roads, cost per cu. yd.	$0.12	0.16	0.21	0.25	0.42	0.60	0.77	0.95	1.39	1.82	2.70	3.58
Good paved roads, cost per cu. yd.	$0.10	0.12	0.14	0.16	0.25	0.34	0.42	0.51	0.74	0.95	1.39	1.82

Notes: Speed on rough dirt roads assumed 10 m.p.h.; on good paved roads, 20 m.p.h.

ROCK EXCAVATION

$1.90 per cu. yd. Cost varies according to size of job; cost based on 4 road jobs, volume of rock 1000 to 7000 cu. yd.

DRILLING AND BLASTING

Cost of powder not included

Soft rock $0.20 per lin. ft. Medium rock $0.30 per lin. ft. Hard rock $0.60 per lin. ft.

Powder per cu. yd. = approximately 1 lb.
Powder cost = 20¢ per lb. in 200-lb. boxes.

TRENCH SHEETING AND WELL POINTS AND LOW DAMS

See also sheeting costs under "Elements of Structure."

Cost Control. E.N.R. Construction Index 294.5. E.N.R. Building Index 231.5. All costs are for Middle Atlantic and New England States. Cost of trench sheeting includes materials and labor for installation and removal; no cost of excavation included. Cost of trench well points includes equipment and labor for installation, pumping, and removal. Costs of low dams are for 1 linear foot of completed dam section as indicated, exclusive of sluices, penstocks, deep excavation and grouting, intakes, etc.

TRENCH SHEETING (Including Bracing)

Costs in dollars per linear foot of trench

Type	Depth, feet						
	6	9	12	15	18	21	24
Horizontal wood	2.15	3.25	4.30	5.40	6.50	7.55	8.65
Vertical wood	3.35	5.05	6.70	9.60	11.50	13.45	15.35
Wood piling, Wakefield, T & G or spline type	4.80	7.20	9.60	13.50	16.20	18.90	21.60
Steel sheet piling	....	....	6.25	7.20	8.15	9.10	10.10

Note: Costs include reuse of material.

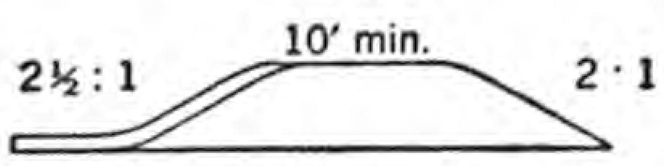
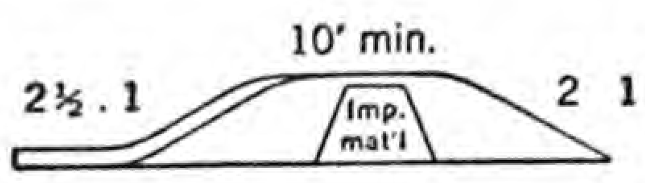
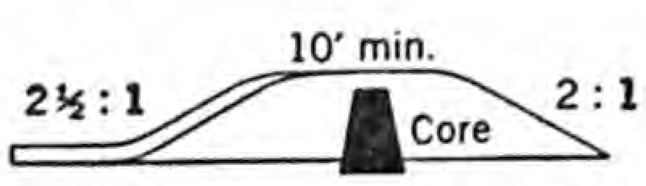
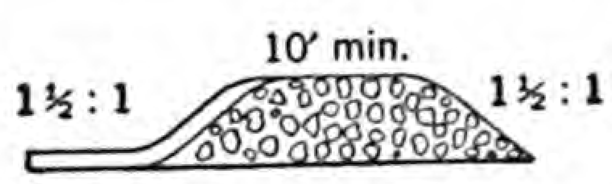
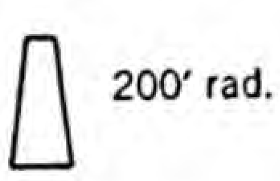
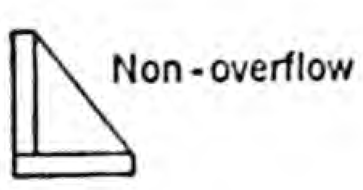
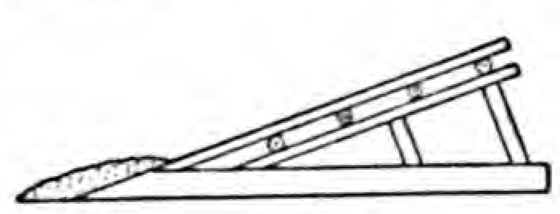
TRENCH WELL POINTS

Cost in dollars per linear foot of trench

Type	Depth, feet			
	6 to 10	10 to 15	15 to 20	20 to 25
Width 4'± Progress 500'/day	2	3	5	8
Width 6'± Progress 350'/day	4	6	8	10
Width 9'± Progress 200'/day	6	8	10	13
Width 12'± Progress 75'/day	8	10	13	15

LOW DAMS

Costs in dollars per linear foot of dam

Type	Section	Height of Water, feet						
		5	8	12	16	20	25	30
Earth, Simple Embank		7.10	10.90	18.00	27.00	37.00	52.50	72.50
Earth, Core Type		8.90	13.70	22.50	33.70	46.25	65.50	90.50
Earth, Diaphragm Type		21.60	31.40	47.00	66.40	90.40	115.00	145.00
Rock Fill		13.20	18.30	27.30	37.60	49.50	66.50	86.50
Gravity, Concrete		25.40	39.30	58.75	81.50	118.50	134.50	193.00
Single Arch, Concrete		13.75	23.00	35.70	52.00	74.00	90.00	117.00
Buttress, Concrete		15.00	20.70	31.50	46.00	66.00	85.00	97.50
Timber		12.50	20.00	35.00	66.00			

Notes: For single arch, 50-ft. radius use 60% of above costs; 100-ft. radius, 65%; 300-ft. radius, 140%; 400-ft. radius, 190%; 500-ft. radius, 230%.

PIPING AND ACCESSORIES

General

Cost Control. E.N.R. Construction Index 294.5, December, 1943. All costs in dollars for items complete in place for New England and Middle Atlantic area.

WATER PIPE

Include Trench in ordinary soil 4 ft. cover

Size, inches	1	2	4	6	8	10	12	16	20	24
Cost per ft. including fittings	1.00	1.25	1.80	2.00	2.90	3.50	4.75	7.50	9.50	12.00

Add 3.00 per ft. for rock. Add 1.00 per ft. for dewatering.

GATE VALVES AND BOXES

Size, inches	2	4	6	8	10	12	16	20	24
Cost	20.00	40.00	50.00	75.00	110.00	140.00	250.00	400.00	600.00

Hydrants (nozzles, two, $2\frac{1}{2}$-in.; one, $4\frac{1}{2}$-in.), each $150.00.

SEWER PIPE

Include Trench in ordinary soil

	Size, inches									
Depth	6	8	10	12	18	24	36	Add for Rock	Add for Sheeting	Add for Dewatering
0 ft. to 6 ft.	0.85	1.00	1.30	1.70	2.50	4.00	6.00	3.00	5.00	1.00
6 ft. to 9 ft.	1.05	1.25	1.60	2.00	3.00	4.50	6.50	5.00	10.00	1.50
9 ft. to 12 ft.	1.40	1.60	2.00	2.50	3.50	5.00	7.00	7.50	14.00	2.50
12 ft. to 16 ft.	2.25	2.50	3.00	3.50	4.50	6.00	8.00	11.50	19.00	3.75
16 ft. to 20 ft.	4.25	4.50	5.00	5.50	6.50	8.00	10.00	15.00	25.00	5.00

Note: All costs are per foot of pipe including fittings.

SEWER MANHOLES

Manholes	14.00 per vertical foot
Add for drop	3.00 per vertical foot
Add for depth over 10 ft.	3.00 per vertical foot
Add for rock	2.00 per vertical foot
Add for dewatering	2.00 per vertical foot

CULVERTS

Include Trench in ordinary soil

PIPE

Size	12″	15″	18″	21″
Cost per ft.	2.00	2.75	3.25	3.75
Size	24″	30″	36″	42″
Cost per ft.	4.25	5.50	7.00	9.00
Size	48″	54″	60″	72″
Cost per ft.	11.00	14.00	18.00	22.50

Catch basin	100.00 each
Drop inlet	75.00 each
Open inlet	60.00 each
Concrete headwalls	25.00 per cu. yd.

Cost Control. E.N.R. Construction Index 294.5. E.N.R. Material Index 120.7. All costs are in dollars per terial cost in carload lots in New York City area. For cost of pipe complete in place, add trenching, sheeting, de-

Note. Items listed opposite 15 in. and 21 in. are for cement asbestos pipe 16 in. and 20 in. in diameter.

Size	*M* or *P*	Double Strength Vitreous Clay	Extra Strength Vitreous Clay	Agri-cultural (Farm) Tile	Plain Concrete	Rein-forced Concrete (Sewer)	Rein-forced Concrete (Culvert) Standard Strength	Rein-forced Concrete (Culvert) Extra Strength Oval or Round	Flat Base Massey	Porous Concrete Pipe (Poros-wall)	Skip-Pipe Vitreous Clay (Robinson)
4	*M* *P*	0.114 0.17	0.19 0.17	0.06 0.12						0.16 0.20	0.12 0.06
6	*M* *P*	0.194 0.20	0.32 0.20	0.12 0.15	0.20 0.20					0.24 0.23	0.21 0.08
8	*M* *P*	0.287 0.25	0.48 0.25	0.19 0.18	0.30 0.25					0.36 0.25	0.32 0.11
10	*M* *P*	0.43 0.30	0.66 0.30		0.35 0.30					0.55 0.30	0.45 0.16
12	*M* *P*	0.55 0.36	0.80 0.36		0.45 0.30	0.75 0.30	0.75 0.30			0.70 0.36	0.65 0.20
15	*M* *P*	0.90 0.45	1.07 0.45		0.60 0.45	1.10 0.45	1.10 0.45			1.20 0.45	
18	*M* *P*	1.325 0.54	1.75 0.54		0.80 0.54	1.20 0.54	1.35 0.54			1.50 0.54	
21	*M* *P*	1.855 0.64	2.55 0.64		1.25 0.64	1.60 0.64	1.75 0.64			2.00 0.64	
24	*M* *P*	2.385 0.75	3.05 0.75		1.50 0.75	1.75 0.75	2.00 0.75	2.25 0.75		2.25 0.75	
27	*M* *P*	3.575 1.20				2.25 1.20	2.50 1.20	2.75 1.20			
30	*M* *P*	3.96 1.40	5.41 1.40			2.50 1.40	2.75 1.40	3.00 1.40			
36	*M* *P*	6.15 1.65	9.20 1.65			3.50 1.65	3.75 1.65	4.00 1.65			
42	*M* *P*					4.50 2.70	4.75 2.70	5.75 2.70			
48	*M* *P*					5.75 2.90	6.00 2.90	6.50 2.90	46 by 46 7.75 2.40		
54	*M* *P*					7.00 3.50	8.00 3.50	10.00 3.50	57 by 57 12.00 3.00		
60	*M* *P*					8.50 4.50	9.00 4.50	12.00 4.50			
66	*M* *P*					10.00 5.75	11.00 5.75	14.00 5.75	68 by 68 17.00 5.00		
72	*M* *P*					12.00 6.50	13.00 6.50	15.00 6.50	80 by 80 22.25 5.50		
84	*M* *P*					15.00 7.50	17.00 7.50	20.00 7.50	91 by 91 28.25 6.50		
96	*M* *P*								97 by 97 38.50 8.50		

CULVERT, AND DRAIN

linear foot of pipe. P = cost of placing pipe in trench in Middle Atlantic and New England States. M = Ma- watering, special bedding, backfilling, and trucking as required. E.N.R. Material Index for corrugated pipe 99.2.

Cement Asbestos				Corrugated Pipe					Corrugated Pipe			M or P	Size
Class 1	Class 2	Class 3	Class 4	16 Gage	14 Gage	12 Gage	10 Gage	8 Gage	Add for Perfora- tions	Add for Full Bitumi- nous Coat	Paved Invert and Full Bitumi- nous Coat		
0.30 0.10											Add $22\frac{1}{2}\%$ for 16 and 14 gage; add 15% for 12 gage; add 12% for 10 gage; add 10% for 8 gage	M P	4
0.41 0.12				0.75					0.05	0.12		M P	6
0.68 0.15				0.85	1.00				0.06	0.15		M P	8
0.82 0.20	0.85 0.20	0.97 0.20		0.95	1.15				0.06	0.15		M P	10
0.98	1.07	1.27		1.05	1.35				0.07	0.20		M P	12
1.45	1.74	2.12		1.35	1.60	2.15			0.08	0.20		M P	15
1.69	2.10	2.59	3.38	1.65	1.95	2.50			0.09	0.30		M P	18
2.07	2.39	3.18	3.62	1.85	2.20	2.95			0.11	0.35		M P	21
2.34	3.55	4.34	4.81	2.05	2.50 .50	3.30	4.25		0.12	0.35		M P	24
												M P	27
3.74	4.77	6.92	7.77		3.25 .60	4.25	5.50		0.15	0.45		M P	30
5.68	6.99	9.60	11.00		3.75 1.35	5.25	6.50	8.00	0.18	0.55		M P	36
						6.10 1.40	7.50	9.10	0.21	0.60		M P	42
						7.20 1.48	8.80	10.40	0.24	0.75		M P	48
						8.65	10.50	12.00	0.27	0.75		M P	54
						10.40	11.85	13.20	0.30	0.90		M P	60
						11.50	13.35	15.15	0.33	1.15		M P	66
						12.60	14.80	17.10	0.36	1.40		M P	72
							16.50	19.00	0.42	1.90		M P	84
							18.00	22.00	0.48	2.40		M P	96

Cost Control. E.N.R. Construction Index 294.5. E.N.R. Material Index 120.7.

All costs are in dollars per linear foot of pipe. P = cost of placing pipe in trench in Middle Atlantic and New
lots in New York City area. For cost of pipe complete in place, add trenching, sheeting, dewatering, and special

A.W.W.A.	Centrifugal Cast and Cement Asbestos
Class A = 43 lb. per sq. in. Class B = 86 lb. per sq. in. Class C = 130 lb. per sq. in. Class D = 173 lb. per sq. in.	Class 50 = 50 lb. per sq. in. Class 100 = 100 lb. per sq. in. Class 150 = 150 lb. per sq. in. Class 200 = 200 lb. per sq. in. Class 250 = 250 lb. per sq. in.

Size	*M* or *P*	A.W.W.A. Cast Iron, B. and S.				A.W.W.A. Cast Iron, Flanged				Centrifugal Cast Iron, B. and S.			
		Class A	Class B	Class C	Class D	Class A	Class B	Class C	Class D	Class 100	Class 150	Class 200	Class 250
2	*M*												
	P												
3	*M*	0.48 *	0.51 *	0.54 *	0.57 *	0.61 *	0.65 *	0.69 *	0.72 *		0.47		0.49
	P	0.20	0.20	0.20	0.20	0.17	0.17	0.17	0.17		0.16		0.16
4	*M*	0.59 †	0.61 †	0.65 †	0.70 †	0.78 †	0.83 †	0.88 †	0.94 †		0.56		0.59
	P	0.23	0.23	0.23	0.23	0.20	0.20	0.20	0.20		0.18		0.18
6	*M*	0.86	0.88	0.95	1.02	1.15	1.22	1.29	1.37		0.82		0.85
	P	0.25	0.25	0.25	0.25	0.22	0.22	0.22	0.22		0.20		0.20
8	*M*	1.20	1.26	1.38	1.48	1.62	1.70	1.89	2.00		1.17	1.21	1.26
	P	0.27	0.27	0.27	0.27	0.24	0.24	0.24	0.24		0.22	0.22	0.22
10	*M*	1.59	1.69	1.88	2.03	2.18	2.34	2.58	2.79		1.57	1.63	1.70
	P	0.32	0.32	0.32	0.32	0.28	0.28	0.28	0.28		0.26	0.26	0.26
12	*M*	2.03	2.17	2.43	2.65	2.85	3.08	3.40	3.69		2.02	2.09	2.18
	P	0.55	0.55	0.55	0.55	0.47	0.47	0.47	0.47		0.44	0.44	0.44
14	*M*	2.51	2.72	3.09	3.42	3.50	3.82	4.28	4.68	2.22	2.48	2.63	2.92
	P	0.75	0.75	0.75	0.75	0.65	0.65	0.65	0.65	0.60	0.60	0.60	0.60
16	*M*	3.04	3.31	3.81	4.19	4.22	4.64	5.30	5.81	2.74	3.09	3.29	3.61
	P	1.00	1.00	1.00	1.00	0.85	0.85	0.85	0.85	0.80	0.80	0.80	0.80
18	*M*	3.62	3.97	4.64	5.08	4.98	5.52	6.35	6.96	3.31	3.72	4.00	4.46
	P	1.30	1.30	1.30	1.30	1.10	1.10	1.10	1.10	1.05	1.05	1.05	1.05
20	*M*	4.20	4.64	5.52	6.08	5.85	6.54	7.52	8.33	3.83	4.34	4.70	5.23
	P	1.80	1.80	1.80	1.80	1.55	1.55	1.55	1.55	1.45	1.45	1.45	1.45
24	*M*	5.72	6.18	7.40	8.13	7.95	8.76	10.20	11.20	5.05	5.80	6.31	7.08
	P												
30	*M*	8.17	8.84	10.60	11.90	11.15	12.65	14.60	16.50		8.05		
	P	2.25											
36	*M*	10.95	12.05	14.45	16.55	15.70	17.20	20.00	23.00				
	P												
42	*M*	14.35	15.65	19.00	21.90	20.60	22.50	26.50	30.30				
	P												
48	*M*	18.65	19.90	24.10	27.80	26.60	28.40	33.50	38.00				
	P												
54	*M*	22.40	24.70	30.20	35.50								
	P												
60	*M*	25.65	29.40	35.50	42.00								
	P												
Cost per ton		56.00	53.00	53.00	53.00	76.00	73.00	73.00	73.00				

* Cost per ton $10 over base.

† Cost per ton $3 over base.

England States, by skilled laborers. Add 100% where union plumbers are used. M = material cost in carload bedding as required. Cost per ton at bottom of table is basis of M cost where listed. Working pressures as follows:

Welded Steel	Wood
Standard Strength = 150 lb. per sq. in.	50-ft. head = 22 lb. per sq. in.
Extra Strength = 200 lb. per sq. in.	100-ft. head = 43 lb. per sq. in.
Double Extra Strength = 250 lb. per sq. in.	150-ft. head = 65 lb. per sq. in.
Large O.D. (outside diameter) = over 250 lb. per sq. in.	200-ft. head = 86 lb. per sq. in.
	250-ft. head = 108 lb. per sq. in.

Cement Asbestos				Welded Steel and Couplings					Wood						
Class 50	Class 100	Class 150	Class 200	Standard Strength	Extra Strength	Double Extra Strength	Large O.D. $\frac{1}{4}$ in. Thick	Large O.D. $\frac{5}{16}$ in. Thick	50-Ft. Head	100-Ft. Head	150-Ft. Head	200-Ft. Head	250-Ft. Head	M or P	Size
0.22	0.24	0.27	0.30	0.13	0.19	0.46								M	2
0.16	0.16	0.16	0.16	0.15	0.16	0.17								P	
0.29	0.32	0.37	0.39	0.28	0.39	1.03								M	3
0.18	0.18	0.18	0.18	0.25	0.26	0.27								P	
0.38	0.44	0.48	0.52	0.42	0.57	1.52			Wire Wound					M	4
0.20	0.20	0.20	0.20	0.30	0.32	0.34								P	
0.59	0.64	0.71	0.85	0.74	1.09	2.93			1.14	1.22	1.31	1.37	1.58	M	6
0.23	0.23	0.23	0.23	0.50	0.53	0.56			0.10	0.10	0.10	0.10	0.10	P	
0.84	0.89	0.99	1.30	0.98	1.70	4.22			1.30	1.43	1.56	1.60	1.85	M	8
0.25	0.25	0.25	0.25	0.67	0.70	0.74			0.12	0.12	0.12	0.12	0.12	P	
1.12	1.23	1.51	1.81	1.29	2.20				1.47	1.66	1.81	1.90	2.15	M	10
0.30	0.30	0.30	0.30	0.80	0.84				0.14	0.14	0.14	0.14	0.14	P	
1.46	1.67	2.00	2.40	1.86	2.70				1.67	1.91	2.08	2.28	2.60	M	12
0.38	0.38	0.38	0.38	1.00	1.05				0.15	0.15	0.15	0.15	0.15	P	
2.03	2.28	2.54	3.16				1.55	1.86	Continuous Stave					M	14
0.46	0.46	0.46	0.46				0.45	0.45						P	
2.54	2.85	3.16	4.16				1.80	2.16	3.50	3.82	4.14	4.46	4.78	M	16
0.55	0.55	0.55	0.55				0.55	0.55	0.36	0.54	0.70	0.86	1.02	P	
3.02	3.39	3.90	5.24				1.97	2.46	3.79	4.12	4.45	4.78	5.11	M	18
0.75	0.75	0.75	0.75				0.65	0.65	0.38	0.56	0.72	0.88	1.04	P	
3.62	4.08	4.54	6.45				2.20	2.75	4.12	4.44	4.76	5.08	5.40	M	20
1.00	1.00	1.00	1.00				0.75	0.75	0.38	0.56	0.72	0.88	1.04	P	
5.00	5.64	6.24	9.72					3.62	4.56	5.04	5.52	6.00	6.48	M	24
								0.85	0.44	0.60	0.78	0.96	1.20	P	
8.10	9.10	10.13	14.26						5.88	6.57	7.26	7.95	8.64	M	30
									0.48	0.68	0.92	1.14	1.38	P	
11.12	12.51	14.75	20.79						7.00	8.20	9.40	10.60	11.80	M	36
									0.58	0.90	1.22	1.54	1.86	P	
									8.30	9.90	11.50	13.10	14.70	M	42
									0.66	1.04	1.60	2.00	2.50	P	
									9.60	12.00	14.40	16.80	19.20	M	48
									0.70	1.44	1.98	2.52	3.06	P	
									12.60	15.10	17.60	20.10	22.60	M	54
									1.14	1.74	2.42	3.08	3.92	P	
									14.30	17.60	20.90	24.20	27.50	M	60
									1.32	2.08	2.88	3.66	4.44	P	
														Cost per ton	

Concrete Water Pipe

Cleveland, July, 1943

24 in., \$5.25
30 in., 6.00
48 in., 16.25
} Complete in place

VALVES AND WATER ACCESSORIES

Cost Control. E.N.R. Material Index 120.7. All costs in dollars for items delivered at job, New York City area.

VALVES, GATES AND DRAINS

Size, inches / Type	2	3	4	6	8	10	12	14	16	18	20	24	30	36	42	48
Gate valves, A.W.W.A., bell end, non-rising stem	9.20	12.60	16.00	26.60	41.15	68.75	90.35	130.10	178.95	243.00	299.65	966.40	845.35	1325.00	1900.00	2670.00
Gate valves, A.W.W.A., bell end, outside screw and yoke	12.10	16.20	20.55	33.85	51.75	87.45	114.85	157.95	208.10	282.75	341.00	524.70	959.00	1480.00	2135.00	2990.00
Globe valves, cast steel	80.00	103.00	134.00	216.00	325.00											
Plug valves, 2-way, flanged ends	8.85	17.01	31.63	62.21	106.85	181.02	353.70		599.94							
Plug valves, 3-way, 2-port flanged ends	17.21	38.39	55.87	91.86	149.60	272.42	455.25									
Butterfly valves, flanged-chain wheel		140.00	165.00	197.00	246.00	328.00	630.00	792.00	993.00	1111.00	1279.00	1693.00	2580.00	4086.00		
Swing check valves, bell or flange	16.24	22.04	31.32	52.20	95.70	145.00	208.80	394.40	522.00	696.00	812.00	1160.00				
Altitude valves, single- or double-acting		183.00	215.00	278.00	400.00	553.00	740.00	1142.00	1355.00	1926.00	2140.00	2865.00	3590.00	4315.00		
Float valves	38.00	62.50	81.00	205.00	240.00	315.00	434.00									
Pressure-reducing valves		218.00	252.00	334.00	465.00	648.00	870.00	1325.00	1560.00	2438.00	2520.00	3365.00	4240.00	5070.00		

Size, inches	3	4	6	8	10	12	14	15	16	18	20	21	24	30	36	42	48
Sluice gates				15.73	16.72	17.60		19.97		30.36		35.70	41.53	80.85	104.89	154.39	186.51
Shear gates	16.00	19.00	23.00	28.50	38.50	47.50	67.00		75.00	85.00	99.00		110.00				

Size, inches	4	6	8	10	12	14	15	16	18	20	21	24	30	36	42	48
Automatic flap-gates			6.05	7.15	8.47		10.73		15.40		20.63	23.76	36.85	50.88	80.30	101.86
Plug drains	16.50	22.75	27.15	39.60	49.65	71.90		96.80	123.20	146.60						

Notes. See pp. 6-78 and 6-79 in "Data Book—Design" for illustrations and uses of valves listed.

Gate Valves. For screw ends add 10%; for flange ends add 15% sizes 3 in. and 4 in., add 8% for sizes over 4 in.

Sluice Gates. Cost includes frame 3 diameters high.

Fire Hose with Couplings—Underwriters Quality

	Pressure (50-ft. Length)					Suction (10-ft. Length)		
Size, inches	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2	$2\frac{1}{2}$	4	5	6
Cost per ft.	$0.30	0.33	0.50	0.60	0.75	$4.80	6.65	9.60

Goosenecks. Lead-wiped with Corporation Stops

Size, inches	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2
Cost	$4.00	6.25	10.75	17.00	26.00

Hydrants

2–$2\frac{1}{2}$ in. nozzles and 1 pumper nozzle included

Valve size, inches	4	$4\frac{1}{2}$	5	6
Cost	$65.00	75.00	85.00	105.00

Note. 5 ft. 0 in. bury cost. Add or deduct $2.50 for each 6-in. variation.

Valve Boxes, 3 ft. deep, $5.00 each. Add $0.50 for each 6 in. deeper.

Air Relief Valve, combination automatic float and poppet, $72.50 each.

WATER TREATMENT

Cost Control. E.N.R. current construction index to be applied to construction index given for cost of sand filters and softeners to bring costs to date.

RAPID SAND FILTRATION PLANTS,* INITIAL COSTS

Location	Year Built	Capacity M.G.D.	Initial Total Cost per M.G.D.
Akron, N. Y.		0.5	$36,000
Proctor, Vt.	1926	0.5	50,000
Ebensburg, Pa.		1.0	42,500
Grove City, Pa.	1928	1.0	45,465
Keansburg, N. J.		1.0	63,295
South Haven, Mich.	1927	1.5	48,400
Williamson, W. Va.	1927	2.0	58,130
Centralia, Ill.		3.0	32,500
Fremont, Ohio	1928	3.0	52,000
Albuquerque, N. M.		4.0	28,800
Mt. Clemens, Mich.	1928	4.0	66,200
Piqua, Ohio	1925	5.0	43,600
Ft. Collins, Col.	1926	6.0	22,662
Wilmette, Ill.	1934	6.0	$59,400
Highland Park, Ill.	1930	7.0	61,700
Topeka, Kan.	1922	8.0	46,800
Michigan City, Ind.	1935	8.0	38,400
Allentown, Pa.	1927	10.0	40,600
Springfield, Ill.	1936	12.00	43,400
Hammond, Ind.	1936	20.00	31,900
Atlanta, Ga.	1923	21.00	34,800
Atlanta, Ga.	1941	33.0	10,800
Dallas, Texas	1930	32.0	31,200
Kansas City, Mo.	1929	100	43,500
Buffalo, New York	1926	160	23,200
Detroit, Mich.	1931	320	25,300

Many of costs included in this table include high and low lift pumping stations and other accessories.

SLOW SAND FILTRATION PLANTS

Initial cost, $100,000 per m.g.d. Operation, $12.00 per m.g.d.

WATER SOFTENERS, INITIAL COSTS *

Location	Year Built	Capacity M.G.D.	Total Cost	Cost per M.G.D.
Columbus, Ohio	1908	54	$600,000	$11,000
Grand Rapids, Mich.	1912, 1924	35.0	1,082,000	31,000
Medina, Ohio	1919	1.0	25,000	25,000
Defiance, Ohio	1921	2.2	250,000	113,000
Westerville, Ohio	1924	0.6	50,000	82,000 (includes pumping station)
Oklahoma City, Okla.	1924	16.0	350,000	22,000 (basins not included)
South Pittsburgh	1924	25.0	1,000,000	40,000
Piqua, Ohio	1925	5	285,000	57,000
Springfield, Ill.	1926	12.0	550,000	46,000
Beverly Hills, Cal.	1928	5.0	248,000	49,600 (filters 5 m.g.d.)
		10.0		24,800 (balance of plant 10 m.g.d.)
Saginaw, Mich.	1929	25.0	2,700,000	108,000 (includes pumping station)
Marion, Ind.	1929	4.0	56,000	14,000 (no filters)
Cedar Rapids, Iowa	1930	12.0	740,000	62,000 (includes pumping station and $2\frac{1}{2}$ miles 24-in. and 30-in. mains)
Bloomington, Ill.	1930	5.0		

WATER SOFTENERS—OPERATING COSTS PER MILLION GALLONS *

Location	Year	Chemical	Operation per 10 p.p.m. Chemical Softening	Chemical	Operation Including Chemical	Including High Lift Pumpage	Average Daily Pumpage	Lime or Lime and Soda	Hardness Reduction p.p.m.
Westerville, Ohio	1929	24.85		14.04		103.05	0.143	L & S	177
St. Louis, Mo. (Chain of Rocks)	1928–29	5.57	9.13	8.70	14.27		118.	L	64
Saginaw, Mich.	1930 (4 mos.)	15.64	25.07	7.18	11.50	37.41	15.41	L & S	218
Grand Rapids, Mich.	1929–30	6.44	15.58	5.60	13.55		18.57	L	115
Marion, Ind.	1930 (June)	15.04	25.00	5.61	9.33		2.41	L	268
Lawrence, Kans.	1929	16.23		10.82			1.41	L	150
Columbus, Ohio	1909–1922	16.38	22.91	9.64	13.47			L & S	170
Beverly Hills, Cal.	1929–30	10.60	24.00	10.60	24.00		3.74	L	100
Springfield, Ill.	1920–30	8.14	17.24	5.45	11.57		7.15	L	149
Bloomington, Ill.	1930 (6 mos.)	11.85		9.12			2.62	L	131
Delaware, Ohio	1930		20.00		11.97			L & S	167
Piqua, Ohio	1930	12.00		5.71				L	210

* Adapted from 1941 "Manual of Water Quality and Treatment" by American Water Works Association.

WATER STORAGE AND WELLS

Cost Control. E.N.R. Construction Index 294.5. Building Index 231.5.

Water tank costs are for item complete in place, New York City area, except cost of riser.

Cost of tanks and reservoir includes roof. Reservoir costs based on 6-in. concrete floor slab and include piping within limits of reservoir.

WATER STORAGE

Elevated Tanks, Cost in Thousands of Dollars

Height to bottom	Type	5	10	25	50	100	250	500	1000
50′	A	2.5	3.0	5.0	6.3	11.7	35.1		
	B	1.8	2.2	4.3	5.6	10.5	31.5		
	C			6.5	7.6	10.7	20.3	43.5	70.0
	D						47.2	68.5	98.0
100′	A	3.6	4.8	7.3	9.2	17.5	36.5		
	B	3.0	4.0	6.4	8.0	15.7	33.5		
	C			8.0	10.0	14.5	25.0	48.5	110.0
	D						58.2	87.5	122.0
150′	A				16.3	25.7	62.2		
	B				13.3	21.5	52.0		
	C			9.5	15.1	18.5	38.2	62.5	135.0
	D						69.2	106.5	146.0

Capacity in 1000 Gallons

Type A. Wood tank, wood tower
Type B. Wood tank, steel tower
Type C. Steel tank, steel tower
Type D. Concrete tank and support

Tanks on Ground, Cost in Thousands of Dollars

Type	5	10	25	50	100	250	500	1000
Wood	0.55	0.95	2.1	3.6	4.8	11.0		
Steel	0.80	1.4	2.7	3.9	5.0	8.5	14.0	25.0
Concrete					5.0	8.8	13.8	21.8

Capacity in 1000 Gallons

Concrete Reservoirs—Cavity Type, Cost in Thousands of Dollars

Capacity in 1000 Gallons

	250	500	1000	2500	5000	8000
Cost	10.0	18.4	33.5	68.7	125.0	160.0

Notes. Ordinary excavation assumed for reservoir; no shale or rocks; good bearing assumed for tank supports.

WELLS

An 8-in., 300-ft. well in rock, pumping 150 g.p.m., costs approximately $6700, including well house and testing.

Setting up Rig, Cost in Dollars

Size of Well	6″	8″	10″	12″
Cost	150	300	400	500

Drilling, Cost in Dollars

Type of Ground	Cost per Inch of Diameter per Foot of Depth
Shale or soft rock, no casing	0.70
Ordinary soil with casing	1.00
Medium rock, no casing	1.00
Hard rock, no casing	1.50

Pump and Electric Motor Units, Cost in Dollars

Horsepower	5	20	50	100	200	250
Capacity, g.p.m.	40	200	500	1000	2000	2500
Diameter	4″	8″	10″	12″	14″	14″
Cost delivered	850	1150	1650	2275	3250	4000
Placing Cost	50	70	90	120	150	200

Notes. 100 lb. discharge pressure 100-ft. deep wells, 3-phase, 220-volt, 60-cycle motors.

Horsepower to be computed from chart on p. 6-14 in "Data Book—Design."

Testing, Cost in Dollars

Size of Well	6″	8″	10″	12″
Cost	60	190	320	450

Screens for Sand or Gravel

Cost, $4.00 per 1 in. of diameter per ft. of length of screen.

Operating Costs. Compute from chart, p. 239.

SEWAGE TREATMENT

Cost Control. E.N.R. Construction Index 294.5. E.N.R. Building Index 231.5, except as noted.

The table entitled "Costs of Sewage Treatment (after Schroepfer)" was published first in 1936, based on data collected during several previous years.

COST OF SEWAGE TREATMENT (AFTER SCHROEPFER) *

Low values are for plants of 100-m.g.d. capacity; high values for plants of 10-m.g.d. capacity.

Type of Treatment Plant †	Cost per Capita—Dollars				Cost per Million Gallons Daily—Dollars				Cost per Million Gallons Treated—Dollars
	First Cost—Cost of Construction	Fixed Charges—Interest and Amortization †	Cost of Operation throughout Year	Annual Expense (c) + (d)	First Cost—Cost of Construction	Fixed Charges—Interest and Amortization ‡	Cost of Operation throughout Year	Annual Expense (g) + (h)	
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
1. Fine screening	0.32–0.40	0.02	0.03–0.06	0.05–0.08	4,000– 5,000	240– 300	420– 700	660– 1,000	1.80– 2.70
2. Plain sedimentation	1.80–2.60	0.11–0.16	0.12–0.18	0.23–0.34	23,000– 32,500	1,380–1,950	1,550– 2,300	2,930– 4,250	10.70–11.60
3. Chemical precipitation §	2.40–4.00	0.14–0.24	0.15–0.28	0.29–0.52	29,500– 50,000	1,750–3,000	1,900– 3,500	3,650– 6,500	10.00–17.80
4a. Low-rate trickling filtration	8.40–9.60	0.50–0.58	0.12–0.24	0.66–0.82	105,000–120,000	6,300–7,200	1,950– 3,000	8,250–10,200	22.60–27.90
4b. High-rate trickling filtration	4.70–5.30	0.28–0.32	0.18–0.25	0.46–0.57	59,000– 66,000	3,500–4,000	2,250– 3,150	5,750– 7,150	15.80–19.60
5. Diffused-air activated sludge	5.50–6.40	0.33–0.38	0.49–0.88	0.82–1.26	69,000– 80,000	4,150–4,800	6,150–11,000	10,000–15,800	28.20–43.20
6. Racks and grit chambers	0.05–0.08	.....	.....	.....	600– 1,000	.....	......	.....	....
7. Rapid filters	0.32–0.40	0.19–0.24	0.21–0.30	0.40–0.54	4,000– 5,000	240– 300	260– 370	500– 670	1.40– 1.90

* From "Sewage Treatment" by Imhoff and Fair.
† Items 1 to 5: Complete plant, including sludge disposal.
‡ At 6%.
§ Excluding cost of chemicals. These may be estimated at $0.25 per capita annually or $8.50 per m.g. treated. Costs may vary by ±25%.

STONE FILTERS

Costs include equipment erected; reinforced concrete at $30.00 per cu. yd.; stone at $3.50 per cu. yd. in place, underdrains at $3.00 per sq. yd. in place; and excavation at $0.90 per cu. yd.

Cost of Filter in Dollars per Pound of B.O.D. Applied Load per Day

Applied Total B.O.D. Load on Filter in pounds per day	100	200	300	400	500	600	700	800	900	1000	1100	1200	1500	2000
High rate filter *	22	18	16	14	13.5	13	12.5	12	11.5	11.5	11	11	10.5	10.5
Low rate filter † 9 ft. deep	61	51	47	45	43	42	41	41	40	40	40	40	....	....
Low rate filter 6 ft. deep	66	57	54	51	50	49	48	47.5	....	....	....	....	....	....

* B.O.D. loading = 1.88 lb. per cu. yd. per day. Costs of recirculating pumps and piping not included.
† B.O.D. loading = 0.23 lb. per cu. yd. per day. Costs of dosing tanks and siphons included.

COMMINUTORS *

Size	Overall Capacity Controlled Discharge in M.G.D.	Cost in Dollars	Size	Overall Capacity Controlled Discharge in M.G.D.	Cost in Dollars
7A	0 to 0.35	1120	25M	1.0 to 6.0	3220
10A	0.17 to 1.1	1525	25A	1.0 to 11.0	4260
15M	0.4 to 2.3	2380	36A	1.5 to 25.0	7250

* Costs given are for ordinary installations and include cost of installing. Consult Chicago Pump Co. for further information.

Cost Control. E.N.R. Building Index 231.5. Costs are for units constructed complete in place in Middle Atlantic or New England States. Good bearing soil is assumed.

BAR RACKS AND AUTOMATIC CLEANING EQUIPMENT

Width of channel	3′ 0″	3′ 6″	4′ 0″	5′ 0″	6′ 0″
Cost in dollars	3500	3750	4000	4450	5100

Note. No building cost included. Cost includes rack, cleaning mechanisms, controls, screenings cans, drainage hopper, auxiliary tools, and installations.

MECHANICALLY CLEANED SEDIMENTATION UNITS

Volume in thousands of cu. ft. per unit	5	10	15	20	25	30	35	40	45	50	60	70	80	90	100
Cost per cu. ft. in dollars	1.20	0.80	0.65	0.60	0.56	0.52	0.48	0.45	0.43	0.40	0.38	0.36	0.35	0.34	0.33

Note. Costs are based on one unit which will include ordinary excavation, all equipment, scum baffles, weirs, wiring, painting, and construction of tank.

SLUDGE DISPOSAL

Two-Stage Digester Costs

Capacity in 1000 cu. ft.	10	20	30	40	50	75	100	200	300	400	500
Costs in thousands of dollars	15.0	29.2	42.6	55.2	66.0	87.5	118.0	224.0	321.0	412.0	500.0

Note. Costs include heating equipment.

SLUDGE BEDS

Open sand beds, \$0.70 per sq. ft. Glass covers for beds, \$1.45 per sq. ft.

Costs are for beds of 6 in. sand over 6 in. gravel, underdrains and collectors, cast-iron distribution pipes and gate valves, wood plank partitions and earth bank walls, and an average earth movement of 2 ft. deep.

VACUUM FILTERS FOR SLUDGE

Filter area in square feet	50	100	200	300	400	500	600	800	1000
Cost in thousands of dollars	12.5	21.5	31.8	41.0	49.0	57.0	63.5	71.5	91.5

Note. Costs do not include housing for filters.

WATER METERS, CHLORINATION, AND WATER-PIPE CLEANING

Cost Control. E.N.R. Material Index 120.7. Cost of meters and chlorinating equipment are for units F.O.B. New York City area. Meter costs are for 100-ft. head and include all gages for direct reading. Chlorinating equipment costs include 50 ft. of rubber hose. Cost of housing chlorinators or contact chambers not included. Cost of cleaning water pipe is for a complete job in Middle Atlantic or New England States.

WATER METERS

Service Meters

Size, inches	$\frac{5}{8}$	$\frac{3}{4}$	1	$1\frac{1}{2}$	2	3	4	6
Cost in dollars	12.60	18.90	26.75	50.40	75.60	144.00	240.00	480.00

Compound Meters

Size	6-2	8-3	10-3	12-4	14-4	16-4	18-5	20-5	24-6	30-8	36-10
Cost in dollars	450	600	750	950	1133	1306	1746	2175	3044	3945	5262

Venturi Tubes

Size	2 x 1	4 x 2	6 x 3	8 x 4	10 x 5	12 x 4	14 x 8	16 x 8	18 x 9	20 x 10	24 x 12	30 x 15	36 x 18	42 x 21	48 x 24
Cost in dollars	625	650	700	745	805	870	970	1065	1170	1290	1580	2070	2580	3105	3680

CHLORINATING EQUIPMENT AND CHLORINE

	Type		
		Automatic	
Size	Manual	Hydraulic	Electric
0 to 100 lb. per day	$1200	$2000	$2500
To 500 lb. per day	Add 1.50 per lb.	Add 2.50 per lb.	Add 2.50 per lb.
Over 500 lb. per day	Add 2.50 per lb.	Add 3.50 per lb.	Add 3.50 per lb.

Hypochlorinators, $200.00±.
Hypochlorites (70% available), $0.35 per lb.
Chlorine gas:
- 150-lb. containers, 8¢ to 12¢ per lb.
- 150-lb. containers in carload lots, $5\frac{1}{2}$¢ f.o.b. R.R. Station.
- 1-ton containers, 3¢ per lb. f.o.b. R.R. Station.

Notes. Cost of installing varies with piping required. Add $200 to values in table for supervision by manufacturer.

WATER-PIPE CLEANING

Size of pipe, inches	4	6	8	10	12	16	20	24
Cost in dollars per lin. ft.	0.18	0.19	0.20	0.22	0.22	0.24	0.25	0.28

PUMPING STATIONS AND PUMPS

Cost Control. E.N.R. Construction Index 294.5. E.N.R. Material Index 120.7.

Costs for water and sewage pumping stations are complete in place in Middle Atlantic and New England States.

Other costs are for units F.O.B. New York City area and include pump with electric motor, 3-phase, 240-volt, and X-line controls, float and float switch, fused motor switch, and automatic starter. No suction lift assumed. All costs are in dollars.

Water pumping station complete in place, 1 m.g.d., $10,000; 4 m.g.d., $30,000.

Sewage pumping station complete in place, $0.025 per gallon per day.

SEWAGE PUMP, CENTRIFUGAL, VERTICAL SHAFT

Head, ft.	10	20	30	40	50	60
Capacity, g.p.m.						
50	375	400	425	400	400	425
100	375	400	425	400	425	425
150	375	425	450	425	425	500
200	385	425	450	425	425	500
350	400	450	475	500	725	750
500	475	475	550	550	750	750
1000	1000	1100	1200	1225	1400	1800
2000	1000	1100	1350	1400	1800	2200
3000	1100	1250	1800	1800	2000	2400

SLUDGE PUMP, PLUNGER TYPE

Head, ft.	up to 8	12	18	25	35
Capacity, g.p.m.					
5 to 75	450	450	450	475	475
75 to 150	625	625	625	650	650
200	800	850	1075	1200	1600

WATER PUMP, CENTRIFUGAL, HORIZONTAL SHAFT

Head, ft.	25	50	75	100	125	150	200	250
Capacity, g.p.m.								
20	150	175	125	200	200	200	250	260
50	160	175	200	225	225	250	250	350
75	175	200	200	225	250	300	325	450
100	185	200	225	250	250	300	400	475
150	200	225	250	300	300	325	400	500
200	200	250	275	300	325	400	500	525
300	225	275	325	325	350	350	350	775
500	300	325	325	375	400	525	700	1150
750	375	400	425	650	650	700	975	1225
1000	375	400	550	650	800	1025	1325	1325
1500	525	700	800	975	1025	1025	1500	1700

Notes. For ordinary cost of installation, add 25% to costs in tables.

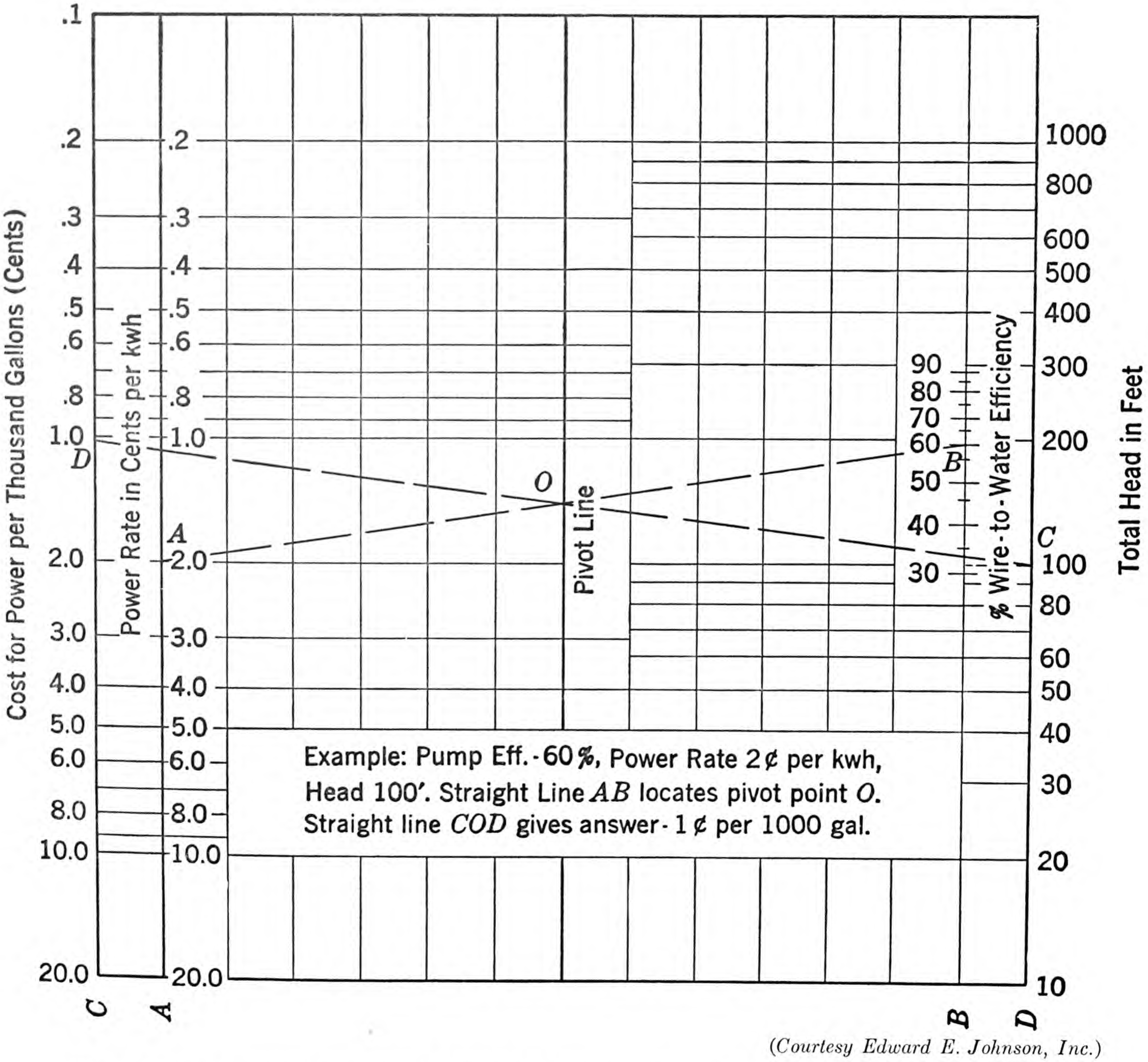
Trucking costs to be added.

SMALL SEWAGE EJECTOR PUMPS

40 to 50 g.p.m. for residences,	250	Including cast-iron or steel receptacle
100 to 300 g.p.m. for apartments,	450	

CHART FOR DETERMINATION OF PUMPING COSTS

This chart is used for determining the power cost of pumping water per thousand gallons when the total head, wire-to-water efficiency, and power rate are known. In using this chart a ruler is placed from line *A* (power rate in cents per kilowatt-hour) to line *B* (per cent wire-to-water pump efficiency). A pin or pencil point is placed against the edge of the ruler on the pivot line and the ruler is then pivoted to the proper point on line *D* (total head in feet). The cost for power per thousand gallons can then be read directly from line *C* at the left of the chart.



(*Courtesy Edward E. Johnson, Inc.*)

Note. If pump efficiency is unknown, use 50% for low head and low capacity; use 75% for high head and high capacity. Ordinary range of power rates $1\frac{1}{2}$ to 3 cents per kwh.

PAINTING AND PAINT MAINTENANCE †

Cost per Ton per Year on Various Bridges

Bridge	Crossing	Location	Type of Superstructure and Tonnage	Years between Complete Repainting	Type of Original Paint	Type of Paint for Repainting	Atmospheric Conditions	Cost of Repaint	Cost of Spot Paint	Total Cost of Paint Maintenance
								¢/T/Yr.	¢/T/Yr.	¢/T/Yr.
A	Mississippi	Southern	Dk. pl. G., twrs. appr. 38,971T Cantilever, through and dk. tr. 19,606T	5	Al. in spar varnish Al. in spar varnish	Al. in glyc. p'thal. var. Al. in glyc. p'thal. var.	Rural Rural	18.2¢	4.4¢ 4.4¢	22.6¢
B	Mississippi	South central	2 sp. c'ntus. through and 6 through tr. 4,700T	8	Graphite in linseed	Graphite in lin. glyc. p'thal.	Mild industrial	22.5¢	15.6¢ *	38.1¢
C	Green	South central	1 through tr. and dk. appr. 700T	8	White lead in linseed	Graphite in glyc. p'thal.	Rural	31.7¢	15.6¢ *	47.3¢
D	Ohio	East central	Cantilever and dk. pl. appr. 2,200T	12	Al. in spar varnish	Al. in glyc. p'thal. var.	Rural	18.5¢	2.0¢ * 4.5¢	25.0¢
E	Mississippi	Northwest central	Sus., 6½ through c'nt., dk. bm. ap. 4,108T	5	White lead in linseed	(Ti., Ba.) in glyc. p'thal.	Mild industrial	51.9¢	1.3¢ * 15.6¢	68.8¢
F	Ohio	South central	Cantilever and dk. pl. appr. 13,931T	6	White lead in linseed	Al. in glyc. p'thal. var.	Industrial	21.5¢	20.1¢	41.6¢
G	Susquehanna	East central	Plate girder spans 1,650T	6	White lead in linseed	(Ti., Ba.) in glyc. p'thal.	Industrial	56.2¢	9.5¢ * 12.1¢	77.8¢
H	Sandusky Bay	North central	Plate girders and lift 1,612T	7	Graphite in linseed	Graphite in glyc. p'thal.	Rural	22.2¢	6.2¢	28.4¢

Additional estimate data for repainting:
- A—1.23 manhours per ton actually painted—3.80T/gal.
- B—1.01 " " " " " —4.13 "
- C—1.09 " " " " " —3.23 "
- D—0.89 " " " " " —3.65 "
- E—0.75 " " " " " —3.45 "

Painter's wages were $0.75 for A, B, C, F.
$1.12½ for D
$1.30 for E

Note: Bridge A is combined railroad and highway bridge; all others are highway structures.
Repainting consisted one complete finish coat over the completely cleaned and spot-primed metalwork.

* Indicates cost of spot painting and cleaning done at time of repainting.

† From *Preparation of Structural Steel Surfaces for Painting*, American Institute of Steel Construction.

RECOMMENDATIONS FOR DETERMINING FEES FOR PROFESSIONAL ENGINEERING SERVICES *

ON FEDERAL AND FEDERAL AID PROJECTS UNDERTAKEN AS AN AID TO INDUSTRIAL RECOVERY OR TO RELIEVE UNEMPLOYMENT

Foreword

The following data and recommendations on fees for professional engineering services have been prepared for use upon Federal or Federal Aid Projects initiated primarily to afford aid to business recovery and relief of unemployment.

The fees recommended are designed to reimburse the Engineer for out-of-pocket expense and a moderate overhead expense, and to afford modest comepnsation to the Engineer for his own time and services. The tabulated fees (Table 1 and Fig. 1) and the comments thereon are founded on the principles set forth in Manual of Engineering Practice No. 5 adopted by the American Society of Civil Engineers on July 7, 1930.

It is contemplated that each engagement will be based upon a contract negotiated at the outset which shall specify which curve for engineering fees is applicable to the problem at hand, or, where neither of the curves applies, shall stipulate the percentage, or per diem fee, to be paid. Statements are presented which are intended to specify exactly what payments, if any, shall be made in addition to the percentage fee, and how such additional payments shall be computed.

Engineering service on a contingent basis is frowned upon. The tabulated fees (Table 1 and Fig. 1) are not adequate to afford compensation for contingent service.

In addition to reliance upon the principles set forth in Manual No. 5, the data presented are intended to reflect the experience of about thirty engineers whose home offices are situated in various parts of the country, and practically all of whom have established businesses which have been conducted for a period of one or more decades.

Fees for Engineering Services

A reasonable fee for engineering services should vary with:

1. The cost of the project.
2. The complication of the project.
3. The extent of engineering services to be furnished by the Engineer.
4. The experience and record of the engineering organization.

The cost of some items of the Engineer's service can be estimated with a moderate degree of certainty; the costs of other items are beyond his control and cannot be estimated closely. Two curves are presented herewith (Fig. 1) for use in estimating a reasonable percentage fee for that portion of the engineering work for which the cost can be determined closely and in advance. These curves are intended to apply to General Work. Higher fees than those indicated by the curves are justified by unusually difficult or complicated projects. Lower fees than those indicated by the curves may be considered appropriate for simple projects which involve simple elements or large duplication of parts.

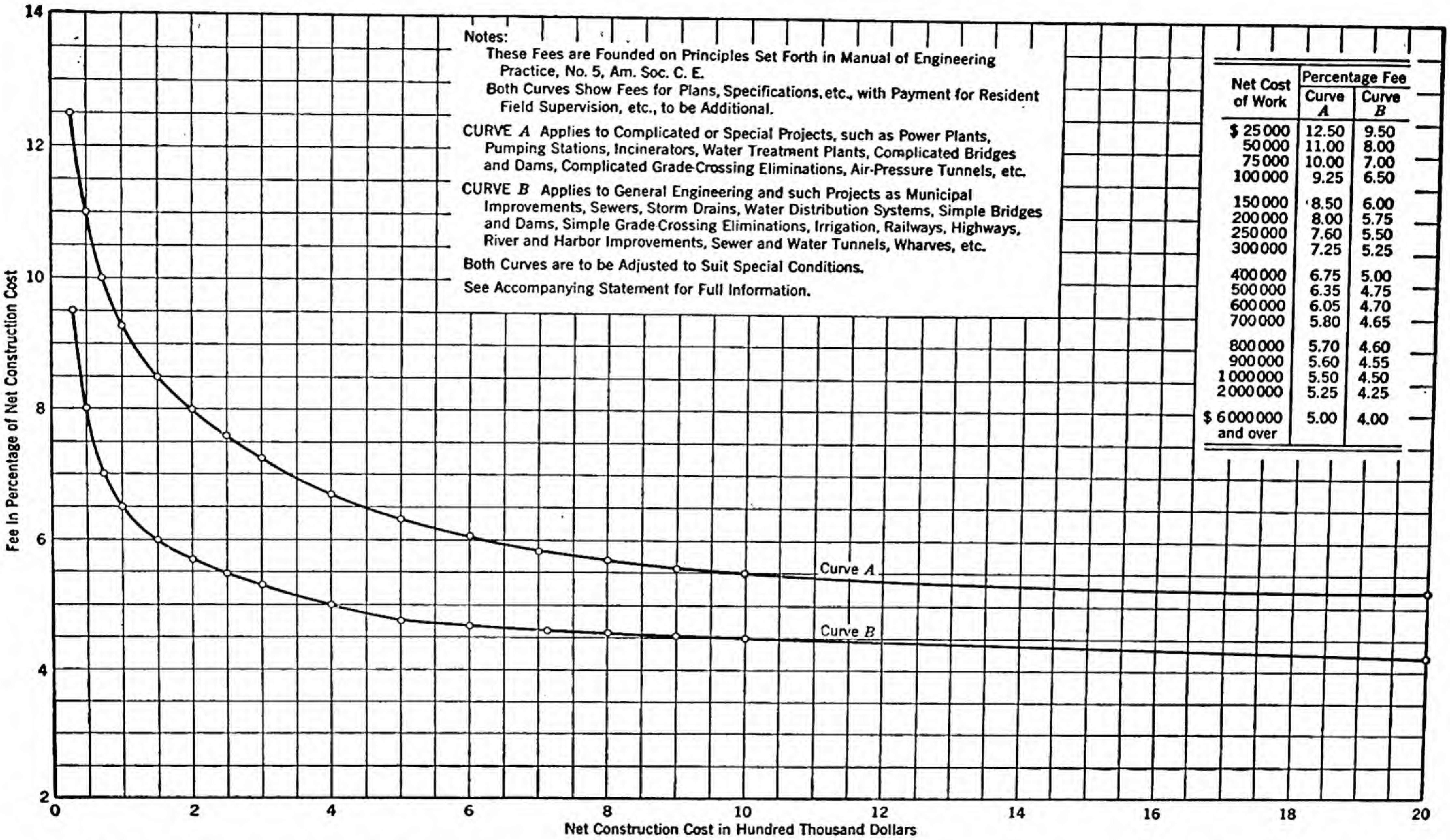
Curve A is intended to apply to highly mechanized or highly complicated projects, such as:

Power plants.
Pumping stations.
Incinerators.
Water and sewage treatment plants.
Complicated bridges.
Complicated grade-crossing eliminations.
Complicated dams.
Air-pressure tunnels.

* From the American Society of Civil Engineers, 1938.

Curve B is intended to cover general engineering services and to apply to such projects as:

Municipal improvements.
Sewers.
Storm drains.
Water-distribution systems.
Simple bridges.
Simple grade-crossing eliminations.
Simple dams.
Irrigation works.
Railways.
Highways.
River and harbor improvements.
Sewer and water tunnels (free air).
Wharves, piers, and docks.



Net Cost of Work	Percentage Fee Curve A	Percentage Fee Curve B
$ 25 000	12.50	9.50
50 000	11.00	8.00
75 000	10.00	7.00
100 000	9.25	6.50
150 000	8.50	6.00
200 000	8.00	5.75
250 000	7.60	5.50
300 000	7.25	5.25
400 000	6.75	5.00
500 000	6.35	4.75
600 000	6.05	4.70
700 000	5.80	4.65
800 000	5.70	4.60
900 000	5.60	4.55
1 000 000	5.50	4.50
2 000 000	5.25	4.25
$ 6 000 000 and over	5.00	4.00

FIG. 1.—RECOMMENDED FEES FOR PROFESSIONAL ENGINEERING SERVICES FOR FEDERAL AND FEDERAL AID PROJECTS.

Work Covered by Fee Taken from Curves. In general, the percentage fee taken from the curves (Fig. 1) should cover such of the following items as may be required:

Preliminary investigations.
Assistance in application for Federal funds.
Preparation of designs, plans, and specifications.
Estimate of quantities and costs.
Assistance in securing bids.
Analysis of bids.
Assistance in letting contracts.
Checking shop and working drawings furnished by contractors.
Consultation and advice during construction.
Reviewing estimates for progress and final payments to contractors.
Final inspection and report.

Items to Be Paid for in Addition to Percentage Fee. The following items of cost cannot be determined accurately in advance and are not within the sole control of the Engineer. They should be paid for in addition to the percentage fee in the manner stated, and the Engineer should keep separate complete accounts of these five items:

1. Field surveys for preliminary investigations.
   To be paid for by reimbursement of actual out-of-pocket expense plus 25% for overhead.
2. Field surveys for design.
   To be paid for by reimbursement of actual out-of-pocket expense plus 25% for overhead.

3. Services of resident engineer.
   To be paid for by reimbursement of actual out-of-pocket expense plus 25% for overhead.
4. Services of field staff additional to services of resident engineer.
   To be paid for by reimbursement of actual out-of-pocket expense plus 25% for overhead.
5. Furnishing reproduction of drawings or plans and specifications.
   To be paid for by reimbursement of actual out-of-pocket expense.

Day Labor Projects. Where advisory services in the management of day labor projects are undertaken, the work required of the Engineer is increased and his fee should be increased by a sum equal to at least 1% of the estimated cost of the project.

Special Tests. The Client should pay directly, and in addition to the percentage fee, for special tests and research, mill and shop inspection of materials and equipment, and for foundation explorations such as borings, test pits, and soil mechanics laboratory investigations.

Alternate Designs. When competitive bids are taken for construction on alternate designs, where this involves the preparation of designs, plans, and specifications for alternate structures, the compensation to the Engineer should be based on the percentage of the actual cost of the work built, plus one-half the same percentage of the bid cost (or estimated cost if no bid) of the alternate designs prepared.

Redesign Required by Owner after Study Designs Have Been Accepted. When redesign of works is required by the Owner after the study designs have been accepted, the Engineer shall be compensated for such redesign at actual out-of-pocket expense and allowance for principals' time, plus 25% for overhead.

Consulting Services. Where consulting, specialist, or expert services are rendered, the Engineer should be compensated upon a per diem basis for all time devoted to the work, including time of travel. For such services the fee should be from $50 to $100 per day, or more, according to the breadth of experience of the Engineer. In all such cases, he should be reimbursed for travel and subsistence expense while away from his home office, in addition to the payment of the fees stated.

Litigation. Contracts for engineering services should include a clause to the effect that nothing in the contract shall be construed to obligate the Engineer to prepare for or appear in litigation in behalf of the Client, except in consideration of additional compensation.

Losses. Contracts should include a clause to the effect that in any event the payment to the Engineer shall not be less than his actual out-of-pocket expense excluding the time of principals.

Work in Conjunction with Architects. In cases where an Architect is engaged to design a building, and an Engineer is engaged to handle the problems of foundation and structural engineering and of mechanical, electrical, and sanitary equipment, the Engineer should be compensated in accordance with the attached tabulation (Table 1) in which fees are given for these special services. The fees for such services are in addition to the Architect's fee.

TABLE 1

ENGINEERING FEES FOR SPECIAL SERVICES IN CONJUNCTION WITH ARCHITECTS

Tabular values are percentages to be applied to the actual cost of that portion of the project upon which the Engineer's services are rendered.

These fees are for use when an Architect handles the principal design but an Engineer is engaged to provide the specific services listed.

Type of Services	Actual Cost of Work Designed by the Engineer (Not Including Cost of Engineering and Architecture)					
	$50,000 or Less	$50,000 to $100,000	$100,000 to $250,000	$250,000 to $500,000	$500,000 to $1,000,000	$1,000,000 and More
Foundation engineering	$7\frac{1}{2}$%	6%	5%	4%	$3\frac{1}{2}$%	3%
Structural engineering *†	6%	5%	$4\frac{1}{2}$%	$3\frac{3}{4}$%	$3\frac{1}{4}$%	$2\frac{3}{4}$%
Equipment: mechanical, electrical, elevators, heating, ventilating, plumbing	6%	5%	$4\frac{3}{4}$%	$4\frac{1}{2}$%	$4\frac{1}{2}$%	$4\frac{1}{4}$%

* For apartment houses and armories increase the fees by $\frac{1}{4}$%.

† In cases where complete structural design is required to resist lateral forces, as in California (the so-called earthquake law), these fees shall be increased appropriately.

This service includes design, drawings, and specifications, and advisory supervision of construction.

This class of work includes such projects as city halls, comfort stations, fire stations, homes for aged, hospitals, municipal auditoriums, and school houses.

Approved by the Board of Direction, April 3, 1935.

IX

GLOSSARY

AIRPORTS

AIRPORT. A landing area used regularly by aircraft for receiving or discharging passengers or cargo.

AIRPORT BEACON.* A beacon located at or near an airport for the purpose of indicating the location of the airport. An airport beacon produces alternate clear and green beams.

AIRPORT LIGHTING.* The application of lights or floodlighting as air-navigation facilities at airports. Airport lighting includes airport beacons, boundary lighting, range lighting, approach lighting, contact lighting, obstruction lighting, traffic-control lighting, and floodlighting.

AIRWAY. An established route of airplane traffic. A "Civil Airway" is an airway on the Federal Civil Airways System 10 miles wide and marked with radio range beams, beacons, and other means.

AIRWAY BEACON.* A beacon, other than an airport beacon, located on or near an airway and used for the purpose of indicating the location of the airway. An airway beacon produces alternate clear and red beams.

ANGLE OF GLIDE. The angle a path of an airplane makes with the horizontal in landing or taking off.

APPROACH LIGHT.* One of a group of lights located outside a landing area to indicate the projection of a runway or landing strip.

APPROACH ZONE.* The area leading from the end of each landing strip within which the approach paths should be kept clear of obstructions. Specifically, the approach zone is commonly considered as a zone increasing gradually in width from 500 ft. at the end of the usable portion of a landing strip to 2,500 ft. at a distance of 2 miles from the center of the landing area.

APRON.* The portion of an airport, usually paved, immediately adjacent to hangars and other buildings, used for parking, loading, and unloading of aircraft.

BEACON.* A light used to indicate a geographical location, producing high-power beams directed slightly above the horizontal, and rotated to produce flashing lights to an observer.

BOUNDARY LIGHT.* One of a series of lights used to indicate the limits of the landing area or a landing field.

CALM.* The absence of appreciable wind. Calm is generally considered as a wind of 3 miles per hour or less.

CEILING PROJECTOR.* A device designed to produce a well-defined illuminated spot on the lower portion of a cloud for the purpose of providing a reference mark for the determination of the height of that part of the cloud.

CIVIL AIRWAY.* A path through the navigable air space of the United States, identified by an area on the surface of the earth, designated or approved by the Administrator as suitable for interstate, overseas, or foreign air commerce. *See also* "Airway."

CODE BEACON.* A beacon having the characteristics of a code light.

CONTACT LIGHT.* One of a series of marker lights, set substantially flush in the ground along a runway, for the purpose of indicating the location of the runway, and assisting aircraft to land and take off. Contact lights are clear along the entire length of a runway except in the final 1,500 ft., where they are yellow and white.

CONTACT OPERATION. Landings and take-offs when airplanes are visible to control tower.

CONTROL PANEL.* A master control panel, usually located in an airport control tower, equipped with light switches and indicating devices for the control of airport lighting.

CONTROL TOWER.* An establishment properly situated and equipped to allow an operator thereof to control air traffic adequately in the immediate vicinity of the airport on or adjacent to which such airport tower is located.

CONTROL ZONE.* The air space above an area within a circle with a radius of 3 miles drawn from the center of a control airport. If, however, a radio directional aid station designed to direct air traffic to the control airport is more than 3 miles from the center thereof, then the control zone is extended above an area 0.5 mile on each side of a line projected from the center of such airport to such radio aid.

COURSE.* The direction over the surface of the earth, expressed as an angle with respect to north, that an aircraft is intended to be flown. It is the course laid out on the chart or map with respect to true north unless otherwise designated. Abbreviation: C. All courses are measured from north through east to 360°.

FLOODLIGHT.* A projector designed to illuminate a surface.

HARDSTANDING. An area in which planes are parked.

INSTRUMENT LANDING.* A landing in which the landing area is approached and the aircraft brought properly to rest upon the ground through the use of radio communication and of instruments installed upon the aircraft.

LANDING AREA.* Any locality, either of land or water, including airports and intermediate landing fields, which is used, or intended to be used, for the landing and take-off of aircraft, whether or not facilities are provided for the shelter, servicing, or repair of aircraft, or for receiving or discharging passengers or cargo.

LANDING LIGHT.* A device designed for use aboard an aircraft to illuminate a ground area from the aircraft.

LANDING STRIP.* A portion of the usable area of an airport, generally 500 ft. or more in width, which in its natural state or as the result of construction work is suitable for the landing and taking off of aircraft under all ordinary weather conditions. The term "runway" is frequently incorrectly used for landing strip.

OBSTRUCTION LIGHT.* A red light which indicates the presence of a fixed object that is dangerous to aircraft in motion.

* Definition from "C.A.A. Design Manual."

Range Light.* A marker light having a distinctive characteristic to indicate the ends of a landing strip or runway. Range lights are green lights, located in groups at the ends of runways or landing strips.

Runway.* The paved surface of an airport used for the landing and taking off of aircraft.

Taxi Lights.* Flush-type lights spaced evenly along the edges of taxiways to guide ships taxiing at night. Taxi lights are blue.

Taxiway.* A paved or unpaved strip over which aircraft may taxi to and from the landing area, runways, or aprons of an airport.

Turnaround. Area where planes turn with one locked wheel; generally at runway ends or in aprons.

Turning Zone. Area outside boundary of airport between or beyond approach zones where airplanes circle while waiting for instructions or signals to land.

Wind Cone.* A tapered fabric sleeve pivoted on a standard to indicate the wind direction.

Wind Direction.* The true direction *from* which the wind blows.

Wind Rose.* 1. A diagram showing the relative frequency and sometimes also the average strength of the winds blowing from different directions in a specified region. 2. A diagram showing the average relation between winds from different directions and the occurrence of other meteorological phenomena.

Wind Tee.* A lighted wind indicator having the form of a tee in a horizontal or slightly tilted plane. A wind tee is marked by green lights.

Wind Tetrahedron. A wind indicator having the form of a tetrahedron in a horizontal position, marked with red and green lights.

BITUMINOUS PAVING

(For uses of bituminous materials see pp. 3-78 and 3-79 of "Data Book—Design.")

Asphalt. Black to dark brown solid or semi-solid cementitious materials; either natural lake asphalt or refined petroleum asphalt. Asphalt is used in combination with crushed rock, gravel, sand, and other aggregates to produce pavements and as a waterproofing or sealing agent for pavements and structures.

Asphalt Block. Fine, dense, graded asphaltic concrete compressed and molded into blocks to be laid in courses like brick pavements. Asphalt block is used for bridge pavements and for heavy urban traffic, usually over a concrete base.

Asphalt Cement (A.C.). Refined asphalt or refined asphalt and flux used for paving purposes.

Asphalt Filler. An asphalt product used to fill cracks and joints in pavements and structures.

Asphalt Mastic. Asphalt cement and mineral material which, when heated, becomes a thick mass to be poured or troweled into place.

Asphalt Penetration. A measure of the hardness or consistency of asphalt expressed as the distance that a standard needle will penetrate a sample under known conditions of temperature, loading, and time. Usual grades are 25 to 200 (200 to 350 sold as SC-6).

Asphaltic Concrete. A bituminous concrete made with asphaltic cement.

Asphaltic Cutback. Asphalt cement dissolved (cut back) with petroleum distillates, to facilitate application and workability. The volatile distillate evaporates, leaving the solid or semi-solid asphaltic bitumen.

Asphaltic Emulsion (Emulsified Asphalt) (A.E.). Asphalt cement emulsified in water with an agent (usually soap). The emulsion is a brown liquid which is applied to aggregates or a surface. As soon as the water evaporates, the asphalt "breaks" or "sets," i.e., turns black. Grades are: SS-1 and 2 (slow setting); MS-1, 2, and 3, (medium setting); RS-1 (rapid setting).

Birdbath. A concavity in a pavement surface which holds water after a shower or rain.

Bitumen. Strictly the portion of bituminous material completely soluble in carbon disulfide; used loosely as a term for any bituminous material, tar, or asphalt.

Bituminous Base Course (Black Base). A foundation for surface and binder courses made of aggregates bound together with bituminous material.

Bituminous Binder. An intermediate course between a base course and a surface course. (Usually Type I, p. 3-75,† etc.)

Bituminous Concrete. A plant mixture of bituminous material with scientifically graded aggregates ranging from as large as $1\frac{1}{2}$ in. down to mineral filler passing a 200 mesh. The mineral filler is usually omitted from base and binder courses. (Type III, p. 3-75,* and curves, pp. 3-76, 3-77,† etc.)

Bituminous Leveling Course. Usually a plant mix of sand and asphalt used to true or crown an old pavement or a rough base before applying a surface.

Bituminous Macadam, Mixing Method. In some localities a term used for coarse stone, gravel, or slag fragments coated with bituminous material in a mixing plant or by mix-in-place methods. (Type I, p. 3-75.†)

Bituminous Mat, Carpet Coat, or Inverted Penetration. A mat of bituminous cemented aggregate, from $\frac{3}{4}$ in. to $1\frac{1}{4}$ in. or more thick, resulting from repetitions of surface treatment and aggregate covering, using viscous bitumens.

Bituminous Material. A combination of asphalt or tar, inert materials, and impurities, distillates, or emulsifiers.

Bituminous Mix-In-Place, Road Mix, or Mulch. A mixture of aggregates and liquid bituminous material mixed directly on the road or runway base by means of blade graders, road drags, harrows, rotary tillers, Pulvi-Mixers, or a traveling plant machine. Two general types are the open and coarse graded type. (Type I and Type II, p. 3-75,† and curves, p. 3-76.†)

Bituminous Pavements. Layers of aggregate over $\frac{3}{4}$ in. thick, coated and cemented together with bituminous material.

* Definition from "C.A.A. Design Manual."

† "Data Book—Design."

BITUMINOUS PENETRATION MACADAM. A pavement constructed by spreading and compacting coarse, uniform rock fragments bound together by aggregate interlock and surface applications of hot asphalt cement, emulsified asphalt, or road tar which penetrate the layer of stone. (Type I, p. 3-75.*)

BITUMINOUS PLANT MIX (BLACK TOP). Aggregates and bituminous materials mixed in a mechanical mixing plant, the finished mix being hauled and laid on the road or runway. (Types I to V inclusive, p. 3-75,* may be plant mixed. Curves, pp. 3-76, 3-77.*)

BITUMINOUS PRIME COAT. Initial application of liquid bituminous material such as MC-0 or RT-1 to a receptive base to penetrate and seal capillary voids, to coat and bond dust and loose particles, and to adhere the base to subsequent courses.

BITUMINOUS SEAL COAT (CARPET COAT). A thin bituminous application (0.2 to 0.35 gal. per sq. yd.) to a surface or wearing course to seal and waterproof small voids and/or to embed sand or chips to provide better traction.

BITUMINOUS STABILIZING OR STABILIZATION. The process of thoroughly mixing soils, gravel, or sand (whether natural soil existing in place, pit-run materials, or graded mixtures) with liquid bituminous materials by blade graders, harrows, rotary tillers, Pulvi-Mixers, travel plants, or other methods. Similar to mix-in-place or road mix.

BITUMINOUS SURFACE TREATMENTS. Applications of bituminous materials to any type of road or pavement surface, with or without aggregate cover.

BITUMINOUS SURFACE OR WEARING COURSE. The top layer of a bituminous pavement.

BITUMINOUS TACK COAT. Very light bituminous application (0.10 to 0.15 gal. per sq. yd.) to a primed base, a binder course, a concrete base, or an existing pavement to insure thorough bond with a surface course.

BLACK TOP. *See* Bituminous plant mix.

COLD MIXES. Plant mixes spread and rolled at normal temperatures. Cold mixes are made of emulsified asphalt, powdered asphalt, liquid asphalt cement, cutback asphalts, or tars and either heated and dried or cold aggregates. Examples are many patented pavements such as Colprovia, Laykold, Amiesite, Tarvia-Lithic, and Bitumuls Concrete.

COLD PATCH. Aggregates and liquid bituminous mixed up by hand or plant and stock piled for patching or maintenance; commonly pit-run gravel mixed with SC-3, MC-3, or RT-5.

FLUSH SEAL. An application of about 0.15 gal. per sq. yd. of material such as RC-1 without cover aggregate.

FLUX OR FLUX OIL. Non-volatile petroleum oil used to soften asphalt.

FOG SEAL. A very thin bituminous application (0.1 gal. per sq. yd.) of material such as MC-0 or RC-0 without cover aggregate.

HOT MIX (BLACK TOP). Plant mixes of the highest type made of hot, dried aggregates and heated asphalt or road tar, spread and rolled while still heated. (Usually Type III and Type IV, p. 3-75.*)

LIQUID ASPHALTS. Products so soft that their consistency cannot be measured by the normal penetration test (such as road oils or asphaltic cutbacks).

MALTHA. A very viscous or stiff asphalt petroleum which hardens rapidly when exposed.

MEDIUM CURING CUTBACK (M.C.). An asphalt cement cut back with kerosene. MC-0 to MC-5.

MINERAL FILLER. A fine mineral product passing a 200-mesh sieve such as pulverized limestone or stone dust. Used in high-type pavements. (Types III and IV, p. 3-75.*)

* "Data Book—Design."

MIXING PLANTS. Mechanical means of storing, drying, heating, and mixing aggregates and bitumen. May be permanent, temporary, traveling, or improvised.

OUTAGE. The gallonage which has been removed from a tank car or distributor or the gallonage which the tank lacks of being full to rated capacity.

PREFORMED ASPHALT JOINT FILLERS. Premolded strips of asphalt cement and cork, sawdust, fiber, mineral matter, etc., for insertion in construction joints of pavements and structures.

RAPID CURING CUTBACK (R.C.). An asphalt cement cut back with gasoline or naphtha. RC-0 to RC-5.

ROAD OIL. Either a slow-curing liquid asphalt or a non-hardening petroleum oil without asphalt, commonly used for dust-laying or surface treatments.

ROAD TAR (R.T.). A bituminous material obtained in making coke from bituminous coal or by cracking petroleum oil vapors. Road tar is classified as liquid or cold road tar, RT-1 to RT-7, and non-liquid or hot road tar, RT-8 to RT-12. There are also cutback tars known as RTCB-5 and RTCB-6.

ROCK ASPHALT. A porous rock which has become naturally filled with asphalt or maltha. Rock asphalt is widely used as a road paving material in the Middle West.

SAND SEAL. An application (approximately 0.25 gal. per sq. yd.) of material such as RC-2, covered by approximately 10 to 20 lb. per sq. yd. of sand cover. Sand seal is very effective for airport runways.

SAND ASPHALT. A mixture of local sand passing a $\frac{1}{4}$-in. or $\frac{3}{8}$-in. sieve and asphalt cement or liquid asphalt without special control of sand grading. Either hot plant mix or cold mix-in-place or plant mix. Sand asphalt is used for low-cost base and surfaces. Type V, p. 3-75,* and curves, p. 3-77.*)

SHEET ASPHALT. A pavement surface composed of graded sand passing a 10-mesh sieve, mineral filler, and asphalt cement. (Type IV, p. 3-75,* and curves p. 3-77.*)

SKIN PATCH. A thin patch on a bituminous pavement to fill a depression or birdbath.

SLOW-CURING LIQUID ASPHALT (S.C.) (ROAD OIL). An asphaltic residue oil or a blend of asphaltic oil with distillates which evaporate slowly. SC-0 to SC-6. (SC-6 is sold in some areas as A.C. 200-350.*)

STONE SEAL (ARMOR COAT). An application of heavy bituminous material (approximately 0.3 gal. per sq. yd.) such as RT-9, 10, or 11, RC-3 or 4 or AC covered with 18 to 40 lb. of crushed rock, slag, or gravel chips per square yard. Repeated applications form an armor coat or inverted penetration.

STONE-FILLED SHEET ASPHALT. A sheet asphalt with coarse stone or chips intermixed but not scientifically graded like asphaltic concrete.

TACHOMETER. An instrument to indicate accurately the feet per minute and gallons per square yard covered by a bituminous distributor.

TAR. *See* Road tar.

TAR CONCRETE. A bituminous concrete made with tar.

TARE. An allowance made for the weight of a container; e.g., at an asphalt plant, the weight of the asphalt bucket including any residue and adhering bitumen.

WASHBOARDS. Transverse corrugations caused on bituminous roads by rubber-tired traffic on unstable mixtures (too rich), thin surfaces, or soft subgrades.

COFFERDAMS AND UNDERPINNING*

Accumulator. A machine used to maintain constant hydraulic pressure in a power-operated system for jacking. An accumulator is essentially a set of two differential pistons with hydraulic pressure on the smaller one and compressed air on the other, together with a compressed-air reservoir and switches which are operated by the moving piston to start and stop the hydraulic pump.

Bent. A group of two or more piles or posts which support a trestle deck or falsework.

Berm. A bank of earth.

Billet. A steel slab for distributing a load (such as a column load) to a grillage or footing.

Blow. Eruption of sand and water inside a cofferdam, causing flooding.

Boil. A run of wet material, usually quicksand, on the bottom of an excavated hole, under the sheeting of an excavation, or under the cutting edge of a caisson, caused by greater water pressure on the outside than on the inside. An ordinary spring is a boil carrying water only.

Borrow. Excavation for the purpose of fill elsewhere.

Brace. A strut or pusher, usually horizontal, though sometimes inclined, of timber or steel, acting in compression to hold earth material or a structure against lateral movement.

Bulb of Pressure. The mass of compressed material under a footing.

Bull Point. A pointed, steel hand drill, used with a striking hammer for breaking off small quantities of rock or masonry.

Bull's Liver. A water-bearing mixture of sand and red clay found in lower Manhattan Island and elsewhere. It quakes when stepped on and is subject to mass movements.

Burn. To cut off with an oxyhydrogen or oxyacetylene flame.

Burning Torch. Equipment for burning with oxyhydrogen or oxyacetylene flame.

Caisson. Watertight box usually of wood or steel sheeting, sometimes a cylinder of steel or concrete, used for the purpose of making an excavation. Caissons may be either open (that is open to the free air) or pneumatic (that is, under compressed air).

Cant. To turn over; to tilt.

Cant Hook. A lever or hook for turning over timbers.

Caterpillar or Crawler. Machine equipped with flexible treads for moving over rough ground.

Check Dam. Dam built for the purpose of retaining sand or earth.

Clay. Heavy, compact, cohesive soil, which is stiff and smooth to the touch when wet and hard when dry. Clay can be drained only very slowly, and it is subject to slow, continuous movement (compression) under load.

Closure. The process of bringing two parts of a cofferdam together to divert a river from its channel.

Cofferdam. Temporary structure built to exclude earth and water from an excavation so that work may be done in the dry.

Cope. To cut a structural-steel member so that another member may be fitted against it.

Critical Size: of Sand. The maximum grain size that will be transported by a given velocity of water.

Cut. An excavation, usually a trench.

Cutoff. A wall or other structure intended to reduce or eliminate percolation through porous strata.

Cylinders. Steel tubes, usually from 10 in. to 60 in. in diameter and from $\frac{1}{8}$ in. to 1 in. in wall thickness. Ten-inch to 24-in. cylinders are usually lap-welded or butt-welded steel pipe in lengths up to 22 ft. Larger cylinders are usually riveted or electrically welded and seldom exceed 8 ft. in length.

Cylindrical Slide. *See* Swedish break.

Dike. Earth dam or embankment.

Dolphin. Cluster of piles driven in water for mooring purposes or for protection against floating objects.

Dry Pack. To fill with concrete by ramming in a damp concrete mixture, usually by means of a piece of timber and a striking hammer.

Earth Auger. A tool for boring holes in the earth, such as post holes, used in underpinning for removing earth from an underpinning cylinder.

Falsework. Temporary bracing for the construction of more permanent work.

Filler Plate. A steel plate or shim used for filling in space between compression members.

Fin. Steel sheeting wall projecting from the main cofferdam structure.

Flow Line. Contour line representing the normal elevation of the water in a reservoir; also the path traced by a particle in a moving body of water.

Foot Block. A mat of timbers, steel, or concrete, to spread the load of a post or shore on the supporting soil.

Footing. The lowest element of a foundation; that part that bears on the soil.

Forebay. Still water impounded upstream from a dam.

Gantry. High movable carriage supporting a crane, whirley, or derrick, usually with underclearance for the passage of trucks, cars, etc.

Grillage. Horizontal members, usually of steel, for spreading the load of a structure over its footing or underpinning.

Groin. Structure built from shore into water for protection against erosion.

Ground Water. Water at, and below, the water table; basal or bottom water; phreatic water; also in a broad sense all water below the ground surface.

Grout. A mixture of cement and water; or of cement, sand, and water; or the same, after setting.

Guide. Element of falsework for aligning sheet piling during setting and driving operations.

Hardpan. A compact, cemented mass of clay with sand, gravel, or boulders, or any two or all of them, usually of glacial origin. The term is rather loosely used but always implies a very dense material, difficult to excavate without picks or the equivalent.

Head. Potential force or pressure of water, due to difference of elevation.

Header. A manifold, or pipe, with branches.

Horsehead. A light framework (or headframe) used over a pit for supporting a pulley block for use in hoisting and lowering men and materials.

Hydraulic. Referring to liquid (usually water) under high pressure, for instance 500 to 8,000 lb. per sq. in.

Hydraulic Jack. A hydraulic cylinder and piston used to raise weights, to force piles, cylinders, and the like into the ground, or to pretest piles, footings, braces, shores, etc. The jack may be operated by a separate hydraulic pump, or the jack and pump may be built as one unit.

Interlock. Combination of grooves and projections at the sides of the units of steel sheet pile for holding one pile to the adjacent piles.

* From White and Prentis, "Cofferdams," and "Underpinning," Columbia University Press.

Interpile Sheeting. Horizontal sheathing, usually of wood, installed between underpinning piles and supported by the piles.

Interpit Sheeting. The same as interpile sheeting but between concreted underpinning pits.

Isotropic. Having the same physical properties in every direction.

Jack. *See* Hydraulic jack.

Jacking Dice. Blocks, usually of 5-in. steel pipe filled with concrete, used for temporary fillers during jacking operations.

Jacking Plate. A steel plate placed on top of a pile during the jacking, to transmit the load of the jack to the pile.

Jackknife. To double up or fold together, like a pocket knife when closed.

Jet. A pipe end or nozzle from which water (or water and compressed air) is emitted under pressure; the water (or water and air) emitted from the nozzle; to use such a jet to loosen the ground to facilitate the driving of a pile, or to loosen and suspend the material in an underpinning pile so that it can be removed by pumping.

Jetty. Structure built out from shore to deflect the current or to minimize its erosive power.

Lateral Movement. Horizontal movement of a structure, earth, sheeting, or bracing.

Lateral Pressure. The horizontal component of the force due to a wedge of earth (and surcharge, if any) moving or tending to move downward along its natural cleavage plane.

Leads. Equipment for guiding and driving piles.

Line Drilling. The drilling of a series of holes in rock along the line to which it is to be excavated. The holes are usually drilled about 4 in. apart, center to center, after which the rock is blasted off with light shots or broken off with plugs and feathers.

Lost Ground. Material which runs into an excavation under or through the sheeting, or as a boil in the bottom; material outside the sheeting which moves downward because of the run or boil, voids left behind the sheeting when it was placed, or movement of the sheeting.

Louvre. Horizontal openings in or between pieces of horizontal sheeting for the purpose of filling any voids which may occur behind the sheeting.

Manometer. Tube containging a liquid the surface of which moves proportionally to changes of pressures; a U-tube; a tube-type differential-pressure indicator; a pressure gage.

Mat or Mattress. Blanket of brush lumber or poles interwoven or otherwise lashed together, placed to cover an area subject to scour, and weighted with rock or concrete blocks or otherwise held in place.

Muck. Excavated material or material to be excavated.

Mucking Tools. Earth auger, small orange-peel bucket, jet, etc., used for excavating underpinning cylinders too small to be entered and dug out by men.

Neat Cement. Portland cement alone, that is, without sand.

Needle. A horizontal beam or group of beams for carrying the load of a column, wall, or other part of a structure, usually while it is being underpinned.

Net Line (Neat Line). The limit within which no material may be let in an excavation. It refers to the sides, not to the bottom or subgrade, of an excavation.

Niggerhead. A winch head or drum on a hoist around which a line can be placed by hand, and the hoisting done by pulling by hand on the line to give it a friction grip on the drum.

Orange-Peel. A type of self-opening and closing bucket in the shape of a half orange peel cut into segments, used on a cable to excavate earth from an underpinning cylinder or elsewhere.

Piezometer. Instrument for measuring pressure head, usually consisting of a small pipe tapped into the side of a conduit and flush with the inside, connected with a pressure gage, mercury, water column, or other device for indicating pressure head.

Pile. A column of wood, steel, and concrete, usually less than 24 in. in diameter, driven or jacked into the ground to support a load. In underpinning, piles are practically always composed of steel cylinders from 12 to 24 in. in diameter, filled with concrete.

Pile Cap. A slab, usually of reinforced concrete, covering the tops of a group of piles for the purpose of tying them together and transmitting to them as a group the load of the structure which they are to carry; also a metal plate often placed on top of steel piles to distribute the load to the concrete from the pile.

Pile Foot. The lower extremity of a pile.

Pile Head. The top of a pile.

Pit. A hole excavated in the ground. In underpinning, a pit is usually sheeted horizontally and seldom goes below water lines; practically never more than a very few feet below water.

Pit Boards (Well Curbing). Horizontal sheeting for retaining the earth about the pit.

Pitot Tube. Device for observing the velocity head of flowing water. It has an orifice held to point upstream in flowing water and connected with a tube by which the rise of water in the tube above the water's surface may be observed. It may be constructed with an upstream and downstream orifice and two water columns, the difference of water levels being an index of the velocity head.

Pool. Still water impounded in a river by a dam.

Porosity. An index of the void characteristics of a soil or stratum as pertaining to percolation; degree of perviousness; also the ratio of void volume to total volume of soil or rock, generally expressed in percentages.

Pretest. The process of testing with hydraulic jacks the bearing capacity of a pile, footing, brace, shore, or other unit of a structure, and of permanently wedging up its load by the patented pretest method. The distinctive feature of the pretest process is that the full test pressure is maintained while the wedging is being done, thus holding in compression the pile, footing, or shore, and the earth on which it bears, or, in the case of a horizontal brace, the brace itself and the members against which it pushes. This eliminates subsequent settlement.

Quicksand. Fine sand (frequently with an admixture of clay) and water which easily runs and boils. Quicksand has also been defined as any granular, water-bearing material that is improperly handled.

Ram. To drive into place or to compact, as to compact relatively dry concrete with a piece of timber and a striking hammer.

Revetment. Material, such as rock, concrete blocks, or mattresses, placed on the bottom or banks of a river to prevent or minimize erosion.

Riprap. Broken stone, in pieces weighing from about 15 to 150 lb. each, placed on earth surfaces for protection against the action of water.

Roller Gate. Hollow cylindrical gate with spur gears at each end meshing with an inclined rack anchored to a recess in the end pier or wall. It is raised or lowered by being rolled on the rack. It may close at a greater depth than its diameter by means of shields or aprons attached to the cylinder.

Run. A flowing of material into an excavation, either under or through the sheeting, or into voids left behind sheeting.

Running Ground. Either water-bearing sand or very dry sand that will not stand up without sheeting.

SAND. Granular material, the grains of which are larger than dust and smaller than gravel.

SCAB. A short piece of timber spiked or bolted to the side of a larger timber, for instance, a 6-in. by 12-in. piece 3 ft. long, bolted to a 12-in. by 12-in. timber.

SCOUR. Removal of sand or earth from the bottom or banks of a river by the erosive action of flowing water.

SCREW JACK. A jack for lifting or lowering, operated by a screw.

SEAL. To close off permanently the bottom of a cylinder, caisson, or other excavation, usually by pouring in grout or concrete, so that water or earth cannot flow in.

SETTLEMENT. Downward movement of a structure, of part of a structure, or of underpinning.

SHEATHING (SHEETING). Horizontal or vertical members of wood or steel placed in contact with earth, usually on a vertical plane, for the purpose of retaining an earth bank in position.

SHEAVE. Grooved pulley-wheel, for changing the direction of a rope's pull.

SHIM. A relatively thin piece of steel used as a filler between two surfaces such as a footing that has been forced down by pretesting and the billet that formerly rested on it.

SHORE. An inclined brace of timber or steel.

SLEEVE. A coupling; for underpinning cylinders, a coupling that is essentially a close-fitting internal band with a shoulder on its outside that bears against the top and bottom of the cylinders joined.

SLIDE. Slip or movement of a bank of earth.

SLOUGH. Secondary river channel or branch through which the current is usually sluggish.

SNATCH BLOCK. A pulley block arranged so that a bight of rope can be entered.

SOFT GROUND. Earth as contrasted to "hard ground" or rock. Usually, with depth, soft ground is water-bearing and semifluid.

SPREADER. A brace between two wales.

SPRING NEEDLE. A needle.

STAGE. Elevation of the surface of a river. The stage depends on such factors as amount of rainfall and runoff.

STREAMLINE. Path of a particle of water which is flowing without turbulence; structure causing such flow, as a fin.

SUBGRADE. The final level to which an excavation (or fill) is to be made.

SUMP. Small depression or excavation in which water is collected for pumping.

SWEDISH BREAK. Slide or movement of clay or earth embankment with characteristic cylindrical or spherical fracture surface.

TAINTOR GATE. Pivoted gate for regulating the flow of water. Its face is usually an arc with the center of curvature at a pivot. (Named from its inventor, Burnham Taintor.)

TALUS. Sloping mass of fragments below a cliff.

TEST. To find the bearing capacity of a pile, pier, or footing, usually by means of hydraulic jacks. Such tests are usually not made up to the full bearing power of the pile or footing, but to some predetermined limit, frequently 150% of the maximum load to be ultimately carried.

TONGUE AND GROOVE. Sheeting (usually wood) in which one edge of the sheet is cut with a projecting tongue that fits into a corresponding groove or recess in the edge of the next sheet.

TRACTIVE EFFORT. Force, exerted by the weight and velocity of water, which tends to cause erosion.

TREMIE. To place concrete under water.

UNDERPINNING. The adding of new permanent support to existing foundations, to provide either additional capacity or additional depth.

VARVED. Banded. A varved clay is one formed by seasonal depositions extending over many years, so that the seasons are indicated by the horizontal bands.

WALE. Beam, either horizontal or vertical, put in contact with sheeting or other beams to hold them in place.

WATER LEVEL. Water table.

WATER TABLE. The surface of the water in the ground.

WEDGE. To tighten up by driving in wedges. In underpinning, proper wedging entails a wedging force greater than the load ultimately to be carried by the unit or underpinning that is being wedged. For heavy structures, this can be accomplished only by pretesting.

WEDGING PLATE. A steel plate placed on top of underpinning or under a footing against which wedges are driven to "pick up" the load of the structure on the underpinning.

WELL CURBING (PIT BOARDS). Horizontal sheeting for retaining the earth about a pit.

WELL POINT. Perforated pipe sunk into sand to permit the pumping of ground water and the exclusion of sand.

WET GROUND. Earth that contains enough water to necessitate excavation methods that are not necessary in dry ground.

WHIP LINE. Single-part hoisting line of a derrick, crane, or pile driver.

WHIRLEY. Large revolving crane mounted on rollers, skids, wheels, or gantry.

WINCH. A small hoist, usually operated by an electric or a gasoline motor.

CONCRETE

(Technical Versions Reworded for Clearness.)

ABSOLUTE VOLUME

$$= \frac{\text{Unit weight}}{\text{Apparent (absolute) specific gravity} \times 62.5}.$$

ABSORBED MOISTURE. Moisture, absorbed by the porosity of the particles of aggregate, that does not add to the volume of the particles. If aggregates are bone dry, the moisture they will absorb is added to the mixing water.

ADMIXTURE. Material added to cement or the concrete mix to increase workability, strength, or imperviousness; to lower freezing point; to prevent scaling; or otherwise to affect the concrete.

AGGREGATES. Sand, gravel, stone, slag, cinders, or other inert material used in the composition of concrete.

AIR-ENTRAINING CEMENTS. Cements interground with resinous or fatty materials such as Vinsol resin, beef tallow, fish oil,

stearate, cod oil, fatty acids, oils, fats, or grease, also various natural and puozzolithic cements. A characteristic is the reduction of unit weight by introducing or entraining air uniformly distributed throughout the mass in microscopic voids. Effects of air-entraining cements are increased resistance to severe frost action, immunity to scaling caused by salt applications, increased workability and less segregation. Loss of compressive and flexural strength is incurred by their use.

ANCHORAGE. The embedment of reinforcement in concrete. (See pp. 1-01,* 1-25 * for ordinary and special anchorage allowable stresses and requirements.)

BLEEDING. The discharge or freeing of water from freshly placed concrete.

CEMENT FACTOR. The number of bags or cubic feet of cement per cubic yard of concrete.

CEMENT-TREATED BASE. A low-grade concrete produced by the addition of cement to a base.

COLUMN.† An upright compression member the length of which exceeds three times its least lateral dimension.

COLUMN STRIP.† A portion of a flat slab panel, one-half panel in width, consisting of the two adjacent quarter panels on either side of the column center lines and extending through the panel in the direction of the span considered for bending.

COMBINATION COLUMN.† A column in which a structural-steel section, designed to carry the principal part of the load, is wrapped with wire and encased in concrete of such quality that some additional load may be allowed.

COMPOSITE COLUMN.† A column in which a steel or cast-iron section is completely encased in concrete containing spiral and longitudinal reinforcement.

COMPRESSIVE STRENGTH OF CONCRETE. The ultimate strength in compression.

CONCRETE.† A mixture of Portland cement, fine aggregate, coarse aggregate, and water.

CONSISTENCY. The degree of fludity as determined by slump test.

CONTROLLED CONCRETE. A term used in the New York City Building Code for concrete for which working stresses are based on the ultimate strength. The mix is designed by preliminary trials and tests to give the ultimate strength desired.

CURING. Any means provided for the retention of moisture in concrete during the process of setting.

DEFORMED BAR.† Reinforcing bars with closely spaced shoulders, lugs, or projections formed integrally with the bar during rolling. Wire mesh with welded intersections not farther apart than 12 in. in the direction of the principal reinforcement and with cross wires not smaller than No. 10 W. & M. gage may be rated as a deformed bar.

DIAGONAL BAND.† A group of reinforcing bars covering a width approximately 0.4 the average span, placed symmetrically with respect to the diagonal running from corner to corner of the panel of a flat slab.

DIRECT BAND.† A group of reinforcing bars, covering a width approximately 0.4 of the distance between columns, placed symmetrically with respect to the center lines of the supporting columns of a flat slab.

DROP PANEL.† The structural portion of a flat slab which is thickened in the area surrounding the column capital.

EFFECTIVE AREA OF CONCRETE.† The area of a section which lies between the centroid of the tensile reinforcement and the compression face of the flexural member.

EFFECTIVE AREA OF REINFORCEMENT.† The area obtained by multiplying the right cross-sectional area of the reinforcement by the cosine of the angle between its direction and the direction for which the effectiveness is to be determined.

* "Data Book—Design."

FINENESS MODULUS. An empirical factor found by dividing the total of the percentages of materials retained on specified sieves by 100. Sieve sizes are as follows (U. S. Series): $1\frac{1}{2}$ in., $\frac{3}{4}$ in., $\frac{3}{8}$ in., Nos. 4, 8, 16, 30, 50, 100.

FLAT SLAB.† A concrete slab reinforced in two or more directions, generally without beams or girders to transfer the loads to supporting columns.

FLEXURAL STRENGTH OF CONCRETE. The modulus of rupture by breaking a test beam in bending. It equals $\frac{6M}{bh^2}$, where M = moment in inch-pounds, b = width in inches, and h = depth in inches.

HONEYCOMB. Lack of solidity in concrete mass due to absence of mortar between larger particles.

LAITANCE. Scum consisting of cement, very fine materials, and water which collects on the top of concrete by reason of an excess of water in the mix.

MIDDLE STRIP.† A portion of a flat slab panel, one-half panel in width, symmetrical about the panel center line and extending through the panel in the direction of the span considered for bending.

NEGATIVE REINFORCEMENT. Reinforcement placed in concrete to resist negative bending moments.

ORDINARY ANCHORAGE. *See* Anchorage.

PANEL LENGTH.† The distance along a panel side from center to center of columns of a flat slab.

PANELED CEILING.† A flat slab in which approximately that portion of the area enclosed within the intersection of the two middle strips is reduced in thickness.

PEDESTAL.† An upright compression member whose height does not exceed three times its least lateral dimension.

PLAIN CONCRETE.† Concrete without reinforcement, or reinforced only for shrinkage or temperature changes.

POSITIVE REINFORCEMENT. Reinforcement placed in concrete to resist positive bending moments.

PROPORTIONS. Ratio in cement of each aggregate and water for a given mix. May be by volume or weight.

RATIO OF REINFORCEMENT.† The ratio of the effective area of the reinforcement to the effective area of the concrete at any section of a flexural member.

REINFORCED CONCRETE.† Concrete in which reinforcement other than that provided for shrinkage or temperature changes is embedded in such a manner that the two materials act together in resisting forces.

SATURATED SURFACE DRY AGGREGATES. Aggregates which contain their limit of absorbed moisture but have no surface or free moisture. They are the basis of most methods of concrete mixture design.

SCREEN OR SIEVE. A device with regularly spaced apertures for separating materials according to size. When not otherwise specified, a "sieve" has rectangular apertures and a "screen" has circular apertures.

SEGREGATION. The unequal distribution of fine and coarse aggregates in the concrete.

SLUMP. The subsidence measured in inches after removal of the mold from a sample of freshly mixed concrete molded in a standard slump cone.

SOIL CEMENT. Stabilization process of improving the characteristics of soil by addition of cement.

SPECIAL ANCHORAGE. *See* Anchorage.

SPECIFIC GRAVITY. The ratio existing between the weight of a material and the weight of water it displaces:

$$\frac{\text{Weight of unit volume of material}}{\text{Weight of water displaced}}$$

† American Concrete Institute definition.

Apparent (absolute) specific gravity of cement or aggregates. Specific gravity of the solid fragments, excluding the volume of the pores. Example: Grain specific gravity for sand might be 2.60.

*Bulk specific gravity.** Specific gravity of the aggregates or cement in an imaginary watertight container, including the volume of the pores. Example: Bulk specific gravity of sand might be 1.8.

SURFACE OR FREE MOISTURE. Moisture on the outside of the particles of aggregates. If aggregates possess surface moisture it is subtracted from the volume of mixing water.

SURFACE WATER.† The water carried by the aggregate except that held by absorption within the aggregate particles themselves.

WATER-CEMENT RATIO. Ratio of water to cement. (See tables, p. 1-28.‡)

WEB REINFORCEMENT. Stirrups, bent bars, or other reinforcement placed to resist shearing stresses in concrete beams.

YIELD. The volume of concrete resulting from a mix of stated quantities of cement, water, and aggregates.

HYDRAULICS—WITH SPECIAL REFERENCE TO IRRIGATION§

In using this glossary, it is essential to understand the following definitions of its scope:

(*a*) There is much confusion concerning the meaning and shades of meaning of many terms used in irrigation practice and the principles of hydraulics connected therewith. The meanings given are intended to be those most widely distributed among those engaged in that field.

(*b*) Terms whose meanings are perfectly obvious, or those whose definitions given in standard dictionaries are sufficient and complete, have generally been omitted.

(*c*) Terms have been included that have broad application but quite restricted meanings when used in irrigation parlance. For such terms, the irrigation shade of meaning is the only one given.

(*d*) The definitions of terms given are not intended to be exhaustive but are quite limited by the significance they have in hydraulics as applied to irrigation practice.

(*e*) The primary attempt has been to record usage. When terms conflict with one another or when their significance is inappropriate or indefinite and confusing, preferential terms have been suggested and in some cases new words have been offered. For example, the "inverted siphon" is a broadly used term, but it is a misnomer. The accepted meaning has been given and then the word "sag pipe" has been presented as a worthy substitute. Another example is provided by the flow characteristics each side of the critical. Such confusion has existed that, as used by various writers, the term "tranquil flow," becomes synonymous with "turbulent flow." It is hoped that the suggestion of the terms "subcritical" and "supercritical" will eliminate any further confusion.

The terms commonly introduced in hydraulics, as applied especially to irrigation, are as follows:

ABSORPTION LOSS. Loss of water from a canal or reservoir by capillary action and percolation during the process of priming. After a canal or reservior has reached a stable condition this loss is called "seepage."

ACRE-FOOT. Quantity of water that would cover 1 acre, 1 ft. deep. An acre-foot contains 43,560 cu. ft.

AERATION. (1) The process of relieving the effects of cavitation by admitting air to the section affected. (2) The process of mixing air or other gases with water, sewage, etc.

AFTERBAY. The tail race of a water-power plant; a pond or reservoir at the outlet of the turbines.

AIR BOUND. The condition of a pipe line wherein air entrapped in a summit prevents the free flow of water through it.

AIR LIFT. A means of raising water by the buoyancy of injected air.

AIR VALVE. A device that releases air from a pipe line automatically without permitting loss of water. It may also admit air to the pipe automatically if the internal pressure becomes less than atmospheric.

ALKALI SOILS. Soils that contain harmful concentrations of mineral salts. In general, black alkali consists of sodium carbonate. Water containing it will dissolve humus, leaving a black residue, which is very detrimental to plants. For the most part, white alkali consists of sodium sulfate; in corresponding concentrations, it is less injurious to plants than the black alkali.

ALLUVIAL CONE. Water-deposited material at the place where mountain stream debouches on to a plain; a debris cone. An alluvial cone carries the suggestion of finer material than a debris cone, which is a mixture of all sizes and kinds.

ANCHOR-ICE. Ice that forms on the bed of a stream.

APRON. A floor or lining of concrete, timber, etc., to protect a surface from erosion, such as the pavement below chutes or spillways, or at the toes of dams.

AQUEDUCT. (1) A major conduit. (2) The entire transmission main for a municipal water supply which may consist of a succession of canals, pipes, or tunnels.

AQUIFER. Water-bearing formations that create a ground-water reservoir.

ARCHED DAM. A curved dam, convex up stream, that depends on arch action for its stability. The load is transferred by the arch to the canyon walls, or other abutments.

AREA CURVES. (1) A graph of the cross-sectional area of a stream at a gaging station or other section. (2) A graph of the surface area of a reservoir plotted against water-surface elevations. (3) A graph of the areas of any structure.

ARID. A term applied to lands or climates that lack sufficient water for agriculture without irrigation.

BACK-WATER CURVE. A particular form of the surface curve of a stream of water which is concave upward. It is caused by an

* Bulk-saturated surface-dry specific gravity means bulk specific gravity based on a surface-dry aggregate containing absorbed moisture. This is the usual specific gravity used in concrete calculations.

† American Concrete Institute definition.

‡ "Data Book—Design."

§ From "Manual of Engineering Practice," Am. Soc. C. E.

obstruction in the channel, such as an overflow dam; the depth is greater at all points than Belanger's critical, and the normal depth and the velocities diminish down stream. The term is also used in a generic sense to denote all water-surface curves. *See also* Surface curve; Drop-down curve.

BAFFLE-PIERS. Obstructions set in the path of high-velocity water, such as piers on the apron of an overflow dam, to dissipate energy and prevent scour.

BAFFLES. A set of vanes or guides, a grid, grating, or similar device placed in a conduit to check eddy currents below them and effect a more uniform distribution of velocities.

BANK STORAGE. Water absorbed by the bed and banks of a stream and returned in whole or in part as the ground-water level falls.

BANKS OF A STREAM. *See* Right bank of stream; Left bank of stream.

BARRAGE. A diversion dam.

BASIN IRRIGATION. A method of irrigating orchards by which each tree is surrounded by a border, to form a pool when water is applied.

BEAR-TRAP DAM. An obstruction built of hinged leaves, that are raised and held up by the pressure of water admitted to the inside. The dam is lowered by draining the interior.

BED LOAD. The quantity of silt, sand, gravel, or other detritus rolled along the bed of a stream, often expressed as weight or volume per time.

BELANGER. *See* Critical velocity.

BENCH-FLUME. A conduit on a bench, cut on sloping ground.

BERM. (1) The space left between the upper edge of a cut and the toe of an embankment. (2) A horizontal strip or shelf built into an embankment to break the continuity of an otherwise long slope.

BERNOULLI'S THEOREM. A proposition advanced by Daniel Bernoulli that the energy head at any section in a flowing stream is equal to the energy head at any other down-stream section plus the intervening losses.

BIFURCATION GATE. A structure that divides the flow between two conduits.

BLOW-OFF. A controlled outlet on a pipe line used to discharge water or detritus.

BORDER. An earth ridge built to hold irrigation water within prescribed limits in a field.

BORDER IRRIGATION. An open field method of flood irrigation between controlling ridges or borders.

BORE. A wave of water having a nearly vertical front, such as a tidal wave, advancing up stream as a result of high tides in certain estuaries; a similar wave advancing down stream as the result of a "cloudburst," or the sudden release of a large volume of water from a reservoir, as in the Johnstown (Pa.) flood. The bore is analogous to the hydraulic jump in that it represents the limiting condition of the surface curve wherein it tends to become perpendicular to the bed of the stream.

BOTTOM CONTRACTION. The reduction in the area of overflowing water caused by the crest of a weir contracting the nappe.

BROAD IRRIGATION. Irrigation with sewage, in which sewage disposal is the primary object.

BROAD-CRESTED WEIR. An overflow structure on which the nappe is supported for a appreciable length; a weir with a significant dimension in the direction of the stream.

BUCKET. (1) A curved surface at the toe of an overflow dam designed to deflect the water horizontally; the transition curve between the overflow face and the apron of a dam. (2) A receptacle on the rim of an impulse waterwheel that receives the impact of the water from the nozzle.

CAISSON. A chamber, usually sunk by excavating within it, for the purpose of gaining access to the bed of a stream or other body of water. If the chamber is closed on top and the water excluded by air pressure, it is called a pneumatic caisson.

CANAL. An open conduit for the conveyance of water, distinguished from a ditch or lateral by its larger size; usually excavated in natural ground.

CAPACITY CURVE. A graph of the volume of a reservoir, tank, etc., as a function of elevations. The capacity of a reservoir can be defined only by reference to some definite elevation.

CAPILLARY WATER. Water held above the water table in soil by capillary force.

CATCHMENT AREA OR BASIN. Watershed; drainage basin; also, the area of such a basin.

CATENARY. *See* Hydrostatic catenary.

CAVITATION. A condition wherein a vacuum, to any degree, exists as a result of flowing water. Complete cavitation obtains when the pressure within the affected part is reduced to that of the vapor pressure of the water.

CENTRIFUGAL PUMP. A water-lifting device that utilizes the centrifugal force imparted to the water by a rapidly rotating runner. It is essentially a reversed inward-flow turbine, the water being admitted to the center of the runner and discharged at its outer periphery. It is not a displacement pump and, therefore, differs materially from a rotary pump.

CHAIN OR TAPE GAGE. A device consisting of a tagged or indexed chain tape or other line attached to a weight which is lowered to touch the water surface, whereupon the gage height is read on a graduated staff or opposite an index. Especially suited to bridges. The graduated staff is generally placed horizontal, the line running over a pulley.

CHANNEL. An elongated open depression in which water may, or does, flow.

CHECK. (1) A structure designed to raise or control the water surface in a canal or ditch. (2) In irrigation terminology, an area of land enclosed in ridges to confine the irrigation water. (A long rectangular area between borders, having a definite slope, is a "strip" and not a "check.")

CHECK IRRIGATION. A method by which a field, divided into compartments or checks, is irrigated by pooling water into them successively.

CHEMICAL GAGING (CHEMI-HYDROMETRY). A process of measuring the flow of water by ascertaining the resulting degree of dilution of a chemical solution of known saturation introduced into the stream at a known rate.

CHEZY FORMULA. A formula expressing the relation between velocity of water, hydraulic radius, and friction slope; thus $V = C\sqrt{RS_f}$, in which V = velocity; R = hydraulic radius; S_f = sine of the slope angle due to friction; and C = a coefficient. *See also* Kutter's formula; Manning's formula.

CHUTE. (1) A high-velocity conduit for conveying to a lower level. (2) An inclined drop or fall.

CIPOLLETTI WEIR. A contracted measuring weir, in which each side of the notch has a slope of 1 horizontal to 4 vertical, to compensate for end contractions; named after Cesare Cipolletti, an Italian engineer.

CLIMATIC YEAR. A year selected for the presentation of data on water supply, precipitation, etc.; the climatic year of the United States Geological Survey extends from October 1 to September 30 following.

COEFFICIENT OF DISCHARGE. Ratio of observed to theoretical discharge. For a siphon this coefficient should be based on the area of the outlet.

COEFFICIENT OF ROUGHNESS. A factor in the Kutter, Manning, Bazin, and other formulas expressing the character of a channel as affecting the friction slope of water flowing therein.

Cofferdam. A barrier built in the water so as to form an enclosure from which the water is pumped to permit free access to the area within.

Conduit. A general term for any channel intended for the conveyance of water, whether open or closed; any container for flowing water.

Consumptive Use. The quantity of water transpired and evaporated from a cropped area.

Continuous Stave-Pipe. A pipe of wooden staves held together by encircling bands; the assembly is made in the field.

Continuous-Flow Irrigation. A system by which each irrigator receives his allotted quantity of water at a continuous rate.

Contour Checks. Compartments of a field made by borders following the contours; a form of terracing.

Contracted Weir. A measuring notch with sides designed to produce a contraction in the area of the overflowing water.

Contraction. The extent to which the cross-sectional area of a jet or nappe is decreased after passing an orifice, weir, or notch. *See also* Vena contracta.

Control. A section or a reach of a conduit where conditions exist that make the water level above it a fairly stable index of discharge. A control may be partial or complete. A complete control is independent of down-stream conditions and is effective at all stages. An overflow dam, a ledge of rock crossing a channel, a boulder-covered reach, and an indurated bed are examples. Controls may be either natural or artificial.

Control Flume. An open conduit or artificial channel arranged for measuring the flow of water, generally including a constricted section wherein Belanger's critical depth exists. *See also* Parshall measuring flume; Venturi flume.

Conversion. A short conduit for uniting two others having different hydraulic elements; a transition.

Conveyance Loss. Loss of water from a conduit, due to seepage, evaporation, or evapo-transpiration.

Core Wall. A wall of masonry, sheet piling, or puddled clay built inside a dam or embankment to reduce percolation.

Cradle. A footing structure shaped to fit the conduit it supports.

Crest. (1) The top of a dam, dike, spillway, or weir; frequently restricted to the overflow portion. (2) The summit of a wave; peak of a flood.

Crib Dam. A barrier made of timber, forming bays or cells which are filled with stone or other suitable material.

Critical Depth. A given quantity of water in an open conduit may flow at two depths having the same energy head. When these depths coincide, the energy head is a minimum and the corresponding depth is Belanger's critical depth.

Critical Flow. A condition of flow for which the mean velocity is at one of the critical values. *See also* Critical velocity; Subcritical flow; Supercritical flow.

Critical Velocity. (1) Reynolds' critical velocity is that at which the flow changes from laminar to turbulent, and where friction ceases to be proportional to the first power of the velocity and becomes proportional to a higher power—practically the square. (2) Kennedy's critical velocity is that in open channels which will neither deposit nor pick up silt. (3) Belanger's critical velocity is that condition in open channels for which the velocity head equals one-half the mean depth. *See also* Critical depth.

Current. The down-stream-moving portion of flowing water.

Current Meter. A device for determining the velocity of flowing water by ascertaining the speed at which the stream rotates a vane.

Cusec. A cubic foot per second.

Cut-and-Fill. A process of building canals by excavating part of the depth and using the excavated material for the adjacent embankments. In a balanced cut-and-fill the excavated material is precisely enough for the embankments, with an allowance for settlement.

Cut-Off. A wall, collar, or other structure intended to reduce percolation of water along otherwise smooth surfaces, or through porous strata.

Cut-Off Trench. An excavation in the base of a dam or other structure filled with relatively impervious material to reduce percolation.

Dam. A barrier to confine or raise water for storage or diversion or to create an hydraulic head.

Datum. Plane of reference for elevations.

Debris. Any material, including floating trash, suspended sediment, or bed load, moved by a flowing stream; detritus.

Debris Cone. A fan-shaped deposit of soil, sand, gravel, and boulders built up at the point where a mountain stream meets a valley, or otherwise where its velocity is reduced sufficiently to cause such deposits. *See also* Alluvial cone.

Debris Dam. A barrier built across a stream channel to store debris, such as sand, gravel, silt, and driftwood.

Deficiency. The amounts by which a series of quantities fall short of a given demand; in other words, the deficiency of a natural stream flow to meet a given irrigation demand determines the storage required, the additional supply necessary, or the limitation of the irrigable area.

Delivery Box. A structure for the control and measurement of water delivered to a farm unit.

Dental. A toothlike projection on an apron, or other surface, to deflect or break the force of flowing water; a form of baffle.

Dentated Sill. A notched sill at the end of an apron to check the force of flowing water and thus reduce erosion below the apron.

Departure. The difference between any single observation and the normal; annual precipitation.

Detritus. *See* Debris.

Dike. An embankment to confine or control water, especially one built along the banks of a river to prevent overflow of low lands; a levee.

Discharge. The quantity of water, silt, or other mobile substances passing along a conduit per unit of time; rate of flow; cubic feet per second; liters per second; millions of gallons per day, etc.

Discharge Curve. A rating curve showing the relation between stage and discharge of a stream.

Distributaries. (1) The smaller conduits taking water out of laterals for delivery to the farms. (2) Any system of secondary conduits. (3) The network of channels on a river delta.

Distribution System. (1) The system of laterals, distributaries, and their appurtenances, conveying irrigation water from the main to the farm units. (2) Any system by which a primary water supply is distributed to consumers.

Ditch. An artificial channel, usually distinguished from a canal by its smaller size.

Diversion Dam. A barrier built for the purpose of diverting part or all of the water from a stream into a different course.

Diversion Duty of Water. *See* Gross duty of water.

Division Box. A structure for dividing and diverting water into other channels. It may divide all flow *pro rata*, or it may divert a definite quantity, within a reasonable tolerance, regardless of the total flow.

Division Gate. A structure that divides the flow between two or more laterals.

Draft Tube. An expanding tube connecting the passages of a turbine with the tail water.

Drain. A conduit for carrying off surplus ground or surface water Closed drains are usually buried.

Drain Tile. Pipe of burned clay, concrete, etc., in short lengths, usually laid with open joints to collect and remove drainage water.

Drainage. (1) The process of removing surplus ground or surface water by artificial means. (2) The manner in which the waters of an area are removed. (3) The area from which waters are drained; a drainage basin.

Drainage Area. (1) The area (square meters, acres, etc.) of a drainage basin. (2) Catchment area; drainage basin.

Drainage Basin. The area from which water is carried off by a drainage system; a watershed or catchment area.

Drainage District. An organization operating under legal regulations for financing, constructing, and operating a drainage system.

Drift Barrier. An open structure built across a stream channel to catch driftwood. It may be of any form from a simple wire fence to a barrier of massive piers with heavy cables strung between them. If feasible the material caught is burned in place at low stages of the stream.

Drop. (1) A structure for dropping the water in a conduit to a lower level and dissipating its surplus energy. A drop may be vertical or inclined; the latter is called a "chute." (2) A fall.

Drop-Down Curve. A particular form of the surface curve of a stream of water, which is convex upward; for example, where a flume discharges freely into the air. The depth at all points is greater than Belanger's critical depth and less than the normal depth, and velocities increase down stream. *See also* Surface curve; Back-water curve.

Drum Gate. A movable barrier in the form of a sector of a circle hinged at the apex. The arc face effects a water seal with the edge of a recess into which the gate may be lowered. The gate is raised and held up by the pressure of water admitted to the recess from the forebay. It is lowered by closing the inlet port to the recess and draining the water from it.

Duration Curve. A graphical representation of the number of times given quantities are equalled or exceeded during a certain period of record. For example, if, in a 10-yr. record of daily stream flow, the percentage of time the flow was above certain values (100, 200, 300 cu. ft. per sec., etc.) was plotted against flow, the graph would constitute a duration curve for that stream and period. From it could be read the percentage of time the flow was greater or less than any given value within the range that occurred during the period cited. The duration curve is the integral of the frequency curve.

Duty of Water. The relation between the area of land served and the quantity of irrigation water used under different standards of practice. It will vary from a large use under crude practice to small use under good practice. It is simply the measure of the use of water and may be distinguished as head gate or gross duty, lateral duty, duty at the farms, or net duty, and crop duty for different crops. It may be expressed in depth of water on the land, as a rate of flow per acre for a given time, or as the area per unit flow for a given time. Strictly speaking, duty should be expressed in terms of the crops that a given quantity of water will produce or the number of acres that a given flow will irrigate. A "high duty," therefore, corresponds to an economical use of water; a "low duty" indicates small returns for the water used. Usage, however, has broadened the meaning until it may mean exactly the opposite; that is, high duty signifying the use of abundant water, and vice versa. *See also* Consumptive use; Water requirement.

Earth Dam. A barrier composed of earth, clay, sand, or sand and gravel, or a combination of earth and rock.

Eddy Loss. The energy lost (converted into heat) by swirls, eddies, and impact, as distinguished from friction loss.

Effective Size (Hazen) (D_{10}). The grain size on a mechanical analysis curve corresponding to $W\% = 10$.

Elastica. *See* Hydrostatic catenary.

End Contraction. The contraction in the area of overflowing water caused by the ends of a weir notch.

Energy. The capacity to perform work: kinetic energy is that due to motion; and potential energy is that due to position. In a stream the total energy at any section is represented by the sum of its potential and kinetic energies. *See also* Energy head; Energy line; Potential energy; Kinetic energy.

Energy Gradient. The slope of the energy line with reference to any plane.

Energy Head. The elevation of the hydraulic grade line at any section plus the velocity head of the mean velocity of the water in that section. The energy of a unit height of the stream. The energy head may be referred to any datum, or to an inclined plane, such as the bed of a conduit.

Energy Line. A line joining the elevations of the energy heads of a stream. The energy line is above the hydraulic grade line a distance equivalent to the velocity heads at all sections along the stream.

Entrance Head. The head required to cause flow into a conduit or other structure; it includes both entrance loss and velocity head.

Entrance Loss. The head lost in eddies and friction at the inlet to a conduit or structure.

Escape. A wasteway for discharging the entire flow of a stream.

Evaporation. The process by which water passes from a liquid or a solid state to vapor.

Evapo-Transpiration. Combined loss of water from soils by evaporation and plant transpiration.

Farm Duty. The seasonal quantity of irrigation water delivered to a farm unit.

Fines. (1) The finer-grained particles of a mass of soil, sand, or gravel. (2) In hydraulic sluicing, the material that slowly settles to the bottom of a mass of water.

Fish Screen. A device intended to prevent the entrance of fish into a conduit.

Fishway, Fish Ladder. A structure with pools and drops to facilitate the migration of fish around dams or other obstructions in streams.

Flashboard. A plank, or slab, generally held horizontally by end girders or by other supports, in a slot, on the crest of a dam or check structure, or in a spillway, to control the water level; a stop plank. *See also* Needle; Stop log.

Float Gage. A chain or tape gage in which a float is substituted for the weight.

Float Gaging. Measurement of the discharge of water by floats to determine velocities.

Flow. A stream of water; movement of water, silt, sand, etc.; discharge; total quantity carried by a stream.

Flow Line. (1) The hydraulic grade line. (2) A conduit, as a pipe, laid on the hydraulic gradient. (3) Flowage line.

Flowage Line. A contour or line around a reservoir, pond, lake, or along a stream, corresponding to some definite water level (maximum, mean, low, spillway crest, etc.). Generally used in connection with the acquisition of rights to flood lands for storage purposes.

Flume. An open conduit of wood, concrete, metal, etc., on a prepared grade, trestle, or bridge. A flume holds water as a complete structure. A concrete-lined canal would still be a canal without the lining, but the lining supported independently would be a flume. A large flume is also termed an aqueduct.

Forebay. (1) A reservoir or pond at the head of a penstock or pipe line. (2) The water immediately up stream of any structure.

Foundation Mattress. A slab of concrete, usually reinforced, placed over a yielding foundation to distribute the superimposed load.

Framed Dam. A barrier, generally built of timber framed to form a water face, supported by struts.

Frazil Ice. Granular or spicular ice which forms in agitated water. Riffles and rapids are prolific sources of such ice during protracted freezing temperatures.

Free Board. The distance between the normal operating level and the top of the sides of an open conduit, the crest of a dam, etc., left to allow for wave action, floating debris, or any other condition or emergency, without overtopping the structure.

Free Flow. A condition of flow through or over a structure not affected by the tail-water level.

Free Water. Water in soil in excess of hygroscopic and capillary water; also termed "gravity water."

Free Weir. A weir that is not submerged—that is, in which tail water is below the crest or the flow is in nowise affected by the elevation of the tail water.

Frequency Curve. A graphical representation of the frequency of occurrence of specific events; for example, if the number of rainstorms of certain designed magnitudes (1, 2, 3 in., etc.) that occurred in a 10-yr. period are plotted against those magnitudes, the resulting graph would constitute a frequency curve of rainfall for that locality and period. The event that that occurs most frequently is termed the "mode." When this coincides with the mean value the curve is symmetrical, but when it differs from the mean, the curve lacks symmetry and is termed a "skew frequency curve."

Friction. *See* Hydraulic friction.

Friction Head (or Loss). The head or energy lost as the result of the disturbances set up by the contact between a moving stream of water and its containing conduit. In laminar flow the friction head is approximately proportional to the first power of the velocity; in turbulent flow to a higher power —practically the square. For convenience, friction losses are best distinguished from losses due to bends, expansions, obstructions, impacts, etc., but there is no recognized line of demarcation between them, and all such losses are often included in the term "friction losses."

Friction Slope. The friction head or loss per unit length of conduit. For most conditions of flow the friction slope coincides with the energy gradient, but where a distinction is made between energy losses due to bends, expansions, impacts, etc., a distinction must also be made between the friction slope and the energy gradient. Friction slope is equal to the bed or surface slope only for uniform flow in uniform channels.

Fringe Water. Water in the zone immediately above the water table. It may consist solely of capillary water, or it may be combined with gravity water in transit to the water table.

Furrow Irrigation. A method of irrigating by small ditches or furrows leading from a header or supply ditch.

Gage. (1) A staff graduated to indicate the elevation of a water surface. (2) A device for registering water levels, flow, velocity, pressure, etc.; a gage.

Gage Height. The elevation of a water surface above or below a datum corresponding to the zero of the staff or other type of gage by which the height is indicated.

Gaging. A measurement of discharge corresponding to a certain stage.

Gaging Station. A selected section in a stream channel equipped with a gage and facilities for measuring the flow of water; a place on a stream where data are gathered by which continuous discharge records may be developed.

Gallery. (1) A subsurface collector for percolating water. (2) A passageway, as in a dam. (3) An underground conduit or reservoir.

Giant. A nozzle, mechanically or hand-controlled, for directing a jet of water for hydraulic sluicing.

Grade. (1) The slope of a road, channel, or natural ground. (2) The finished surface of a canal bed, road bed, top of embankment or bottom of excavation. (3) Any surface prepared for the support of a conduit, paving, ties, rails, etc.

Gradient. Change of elevation, velocity, pressure, or other characteristic per unit length; slope.

Gravity Dam. A dam depending solely on its weight to resist the water load.

Gravity Ground Water. The water that would drain from a given soil zone if the zone were subject to the unimpeded action of gravity. The term is indefinite as the quantity is dependent upon period for draining, temperature, and other factors.

Gravity Water. (1) Water that moves through soil under the influence of gravity. (2) A gravity supply of water as distinguished from a pumped supply

Gross Duty of Water. The irrigation water diverted at the intake of a canal system, usually expressed in depth on the irrigable area under the system; diversion requirement.

Ground Water. Water at, and below, the water table; basal or bottom water; phreatic water. Used also in a broad sense to mean all water below the ground surface.

Groyne (Groin). A spur-dike. *See also* Wing dam.

Head. The height of water above any point or plane of reference. Used also in various compounds, such as energy head, entrance head, friction head, static head, pressure head, lost head, etc.

Head Gate. The control works, or the gate itself at the entrance to a conduit.

Head Race. A channel leading water to a water wheel; a forebay.

Head Water. (1) The water up stream from a structure. (2) The source of a stream. *See also* Forebay.

Head Works. The diversion structures at the head of a conduit; an intake heading.

Hollow Dam. A barrier usually of reinforced concrete consisting essentially of slabs supported by transverse buttresses. The load is taken by the slabs and transferred to the foundations through the buttresses. *See also* Multiple-arch dam.

Hook Gage. A pointed hook attached to a graduated staff or vernier scale for measuring, accurately, the elevation of the surface of still water. The hook is submerged, and then raised until the point makes a pimple on the water surface.

Hydraulic Elements. The depth, area, perimeter, mean depth, hydraulic radius, velocity, energy, and other quantities pertaining to a particular stage of flowing water.

Hydraulic Friction. A force-resisting flow which is exerted on contact surface between a stream and its containing channel. It usually includes the normal eddies and cross currents attendant upon turbulent flow occasioned by the roughness characteristic of the boundary surface, moderate curvature, and normal channel variations. Wherever possible, the effects of excessive curvature, eddies, and impact, obstructions, and pronounced channel changes are segregated from the effects of hydraulic friction.

Hydraulic Grade Line. In a closed conduit a line joining the elevations to which water could stand in risers. In an open conduit, the hydraulic grade line is the water surface.

Hydraulic Gradient. The slope of the hydraulic grade line. The slope of the surface of water flowing in an open conduit.

HYDRAULIC JUMP. The sudden and usually turbulent passage of water from low stage below critical depth to high stage above critical depth during which the velocity passes from supercritical to subcritical. It represents the limiting condition of the surface curve wherein it tends to become perpendicular to the stream bed.

HYDRAULIC RADIUS. The right cross-sectional area of a stream of water divided by the length of that part of its periphery in contact with its containing conduit; the ratio of area to wetted perimeter.

HYDRAULIC RAM. A device for lifting water by the water hammer produced by checking the flow periodically.

HYDRAULIC SLUICING. The process of moving materials by water; colloquially, "hydraulicking."

HYDRAULIC-FILL DAM. A dam composed of earth, sand, gravel, etc., sluiced into place; generally the fines are washed toward the center for greater imperviousness.

HYDROGRAPH. A graph showing the stage, flow, velocity, or other property of water, with respect to time.

HYDROGRAPHER. A person in charge of the measurements of discharge, precipitation, run-off, etc.

HYDROGRAPHY. Water surveys. The art of measuring, recording, and analyzing the flow of water; and of measuring and mapping water courses, shore lines, and navigable waters. *See also* Hydrometry.

HYDROLOGY. The science treating of the waters of the earth in their various forms. Precipitation, evaporation, run-off, and ground water.

HYDROMETRY. The measurement and analysis of the flow of water.

HYDROSTATIC CATENARY. The curve assumed by a non-extensible but flexible cord when subject to a normal load at all points proportional to the distance below the horizontal line joining its supports; also termed the "Elastica." The shape which a semicircular flume tends to assume when carrying water.

HYGROSCOPIC COEFFICIENT. The moisture, in percentage of dry weight, that a dry soil will absorb in saturated air at a given temperature.

HYGROSCOPIC MOISTURE OR WATER. Immobile soil moisture that can be driven off only by heat.

IMPACT. The striking together of two masses. When particles or streams of water suffer impact, energy losses result.

IMPACT LOSS. The head lost as a result of the impact of particles of water; included in and scarcely distinguishable from eddy loss.

IMPERVIOUSNESS. That quality or condition of a material that minimizes percolation.

IMPROVED VENTURI FLUME. *See* Parshall measuring flume.

INCLINED GAGE. A staff gage on a slope graduated to read vertical heights above the datum.

INDICATOR. A device that shows by an index, pointer, dial, etc., the instantaneous value of such quantities as depth, pressure, velocity stage, or the movements or positions of water-controlling devices; a gage. *See also* Recorder; Register.

INFILTRATION. The percolating flow of ground water into a drain, gallery, or other underground conduit.

INLET. (1) A surface connection to a closed drain. (2) A structure at the diversion end of a conduit. (3) The up-stream end of any structure through which water may flow.

INTAKE. The head works of a conduit; the place of diversion.

INTEGRATION METHOD. A means of determining the mean velocity at a vertical of a stream by noting the total number of revolutions of a current-meter vane, and the time consumed, while the meter is slowly lowered from the surface to the bed and returned one or more times.

INTENSITY OF PRESSURE. The pressure per unit area.

INTERCEPTING CHANNEL. A channel excavated at the top of earth cuts, or at the foot of slopes, or at other critical places to intercept surface flow; a catch drain.

INTERCEPTION. Precipitation caught by vegetation and evaporated before reaching the ground.

INVERT. The floor, bottom, or lowest part of the internal cross section of a conduit.

INVERTED SIPHON. A pipe line crossing over a depression or under a highway, railroad, canal, etc. The term is common but inappropriate, as no siphonic action is involved. The term "sag pipe" is suggested as a substitute.

IRRIGABLE AREA. The area under an irrigation system capable of being irrigated principally as regards quality and irrigation of land. It generally includes roads, farm lots, building sites, and miscellaneous areas not actually irrigated.

IRRIGATING HEAD. (1) The flow used for irrigation of a particular tract of land. (2) The flow of water distributed at a single irrigation, or that in a single farm lateral. (3) The flow rotated among a group of irrigators.

IRRIGATION. The artificial application of water to lands for agricultural purposes.

IRRIGATION DISTRICT. An organization operating under legal regulations for financing, constructing, and operating an irrigation system.

IRRIGATION REQUIREMENT. The quantity of water, exclusive of precipitation, that is required for crop production. It includes economically unavoidable wastes.

IRRIGATION WATER. The quantity of water artificially applied in the processes of irrigation. It does not include precipitation.

IRRIGATOR. One who applies water to land for growing crops.

JETTY. A dike built of piles, rock, or other material, extending into a stream or into the sea at the mouths of rivers to induce scouring or bank building, or for protection.

JUMP. *See* Hydraulic jump.

KENNEDY. *See* Critical velocity.

KINETIC ENERGY. Energy due to motion. The kinetic energy of a given discharge is generally taken as proportional to the product of its weight per unit of time and the velocity head of its mean velocity. For a constant discharge, kinetic energy may be represented by a line at a distance above a flowing water surface proportional to the velocity head of its mean velocity. The elevation of such a line above any datum represents the total energy (potential plus kinetic) of the given discharge above that datum. Strictly, the kinetic energy of a given discharge is the integral of the kinetic energies of its particles.

KUTTER'S FORMULA. An empirical formula expressing the value of the coefficient, C, in the Chezy formula, in terms of the friction slope, hydraulic radius, and a coefficient of roughness.

LAMINAR FLOW. That type of flow in which each particle moves in a direction parallel to every other particle, and in which the head loss is approximately proportional to the first power of the velocity. It is sometimes designated "streamline flow" or "viscous flow."

LAMINAR VELOCITY. That velocity below which, in a particular conduit, laminar flow will always exist, and above which the flow may be either laminar or turbulent, depending on circumstances.

LATERAL. (1) A conduit diverting water from a main conduit, for delivery to distributaries. (2) A secondary ditch.

LATERAL-FLOW SPILLWAY. A spillway in which the initial and final flow are approximately at right angles to each other; a side-channel spillway.

LEACH. To remove alkali from soils by abundant irrigation combined with drainage.

LEFT BANK OF A STREAM. The left-hand bank when one is looking down stream.

Length-of-Run. (1) The distance water must run in furrows or over the surface of a field from one head ditch to another, or to the end of a field. (2) The period of time that one irrigator is allowed the irrigating head, in the system of rotation deliveries.

Levee. A dike or embankment for the protection of lands from inundation, or for the purpose of confining stream flow.

Leveler. A buck scraper, drag, or any other form of device for smoothing land for irrigation.

Lining. A protective covering over all, or over a portion, of the perimeter of a conduit, or reservoir, to prevent seepage losses, to withstand pressure, or to resist erosion. Conduits are sometimes lined to reduce friction or otherwise improve conditions of flow.

Log Chute, Logway. A bypass around or through a dam for logs and drift.

Lost Head. The energy of a given flow that is lost (converted into heat and, therefore, useless), as a result of friction, eddies, and impact expressed as a head, that is, as the height through which that flow would have to fall to produce an equivalent amount of energy.

Machine-Banded Pipe. A pipe made of wooden staves. The assembly is held together in a machine and tightly wrapped with wire. The pipe is made in definite lengths and joined in the field by couplings. Such pipe is rarely made larger than 24 in. in diameter.

Main Canal. The main conduit beginning at the source of water supply, from which the lateral system receives its supply.

Manning's Formula. An empirical formula for the value of the coefficient, C, in the Chezy formula, the factors of which are the hydraulic radius and a coefficient of roughness; a simplification of the Kutter formula.

Manometer. A tube containing a liquid, the surface of which moves proportionally to changes of pressures; a U-tube; a tube type of differential pressure indicator; a pressure gage.

Mass Diagram. A graphical representation of cumulative quantities, such as the integral of a time-flow curve; an integral curve; each point on the curve is the sum of all preceding quantities considered. The diagram is used extensively in storage analyses.

Mattress. A blanket of brush or poles interwoven or otherwise lashed together and placed to cover an area subject to scour, weighted with rock, concrete blocks, or otherwise held in place.

Mean Depth. Cross-sectional area of a stream divided by its surface width.

Mean Velocity. (1) The velocity at a given section of a stream obtained by dividing the discharge of the stream by the cross-sectional area at that section. (2) Mean velocity may also apply to a reach of a stream by dividing the discharge by the average area of the reach.

Measuring Weir. A device for measuring the flow of water. It generally consists of rectangular, trapezoidal, triangular, or other shaped notch in a thin plate in a vertical plane through which the water flows. The weir head is an index of the rate of flow. *See also* Cipolletti weir; Rectangular weir; Triangular weir.

Miner's Inch. The discharge from an orifice 1 in. square under a definite head. It is a rate of flow. The value of a miner's inch has been fixed by statute in various states as follows: In Arizona, California, Montana, and Oregon, 40 miner's in. are the equivalent of 1 cu. ft. per sec.; in Idaho, Nebraska, Nevada, New Mexico, North Dakota, South Dakota, and Utah, 50 miner's in. are the equivalent of 1 cu. ft. per sec.; in Colorado, the accepted equivalent is 38.4, and, in British Columbia, 35.7. In some parts of California 40 miner's in. to 1 cu. ft. per sec. is used, whereas in the southern part quite generally 50 miner's in. to 1 cu. ft. per sec. is used, regardless of the legal definition.

Module. A device for delivering a definite quantity or discharge of water, or for measuring and controlling the flow.

Moisture Equivalent. An arbitrary ratio used in the indirect determination of hygroscopic and wilting coefficient of soils. It is given in terms of $100\frac{c}{W}$ in which c = weight of water that remains in the soil sample after it has been saturated and subjected to a centrifugal force 1,000 times that of gravity; and W is the weight of the soil sample when dried.

Movable Dam. A barrier that may be opened in whole or in part. The movable part may consist of gates, stop logs, needles, wickets, or any other device whereby the area for flow through or over the dam may be controlled.

Multiple-Arch Dam. A barrier consisting of a series of arches supported by buttresses or piers. The load is transferred by the several arches to the foundation through the buttresses.

Nappe. A sheet or curtain of water overflowing a weir, dam, etc. The nappe has an upper and a lower surface.

Needle. A timber set on end to close an opening for the control of water; it may be either vertical or inclined; a form of stop plank.

Net Duty of Water. The depth of irrigation water applied to a farm unit; farm duty. *See also* Duty of water.

Neutral Depth. *See* Normal depth.

Non-Uniform Flow. A flow the velocity of which is undergoing a positive or negative acceleration. If the flow is constant it is referred to as "steady non-uniform flow."

Normal. A mean or average value established from a series of observations, for purposes of comparison; for example, the normal for annual precipitation as used by the United States Weather Bureau is the average of at least 10 yr. of record and is changed only at 10-yr. intervals.

Normal Depth. The depth of water in an open conduit that corresponds to uniform velocity for the given flow. It is a hypothetical depth under conditions of steady non-uniform flow; the depth for which the surface and bed are parallel; also termed the "neutral" depth.

Normal Year. A year of normal or average water supply.

Notched Weirs. *See* Measuring weir.

Ogee. The reversed curve of the face of an overflow dam.

Operation Waste. The water wasted through spillways or otherwise discarded from an irrigation system after having been diverted into it.

Orifice. (1) A hole or opening, usually in a plate, wall, or partition, through which water flows, generally for the purpose of control or measurement. (2) The end of a small tube, as the orifice of a Pitot tube, piezometer, etc.

Orifice Plate. A plate containing an orifice. In pipes, the plate is usually inserted between a pair of flanges. The orifice is smaller than the pipe, and the drop in the hydraulic grade line caused thereby is an index of the discharge.

Outfall. The point where water flows from a conduit; the mouth of drains and sewers.

Over-Fall. (1) The part of a dam or weir over which the water pours. (2) The over-pouring water.

Overflow Stand. A standpipe in which water rises and overflows at the hydraulic grade line.

Overhaul. The transportation of excavated material beyond certain specified limits.

Parabolic Weir. A measuring weir whose notch is bounded on the sides by parabolas such that the flow is proportional to the head.

Parshall Measuring Flume. (Formerly termed the "improved Venturi flume." A calibrated device developed by engineers of the U. S. Department of Agriculture, of whom Ralph L. Parshall, Assoc. M. Am. Soc. C. E., has been the principal experimenter. Its purpose is to measure the flow of water in open conduits. It consists essentially of a contracting length, a throat, an expanding length. At the throat is a sill over which the water is intended to flow at Belanger's critical depth. The upper head is measured a definite distance up stream and the lower head a definite distance down stream from the sill. The lower head need not be observed except where the sill is submerged more than about 67%. A special form of control flume. *See also* Control flume; Venturi flume.

Penstock. A closed conduit for supplying water under pressure to a water wheel or turbine.

Percolation. Movement of water through the interstices of a substance, as through soils.

Permissible Velocity. The highest velocity at which water may be carried safely in a canal or other conduit; the highest velocity throughout a substantial length of a conduit that will not scour.

Phreatic Water. Subsurface water; ground water; free water.

Piezometer. An instrument for measuring pressure head, usually consisting of a small pipe tapped into the side of a closed or open conduit and flush with the inside, connected with a pressure gage, mercury, water column, or other device for indicating pressure head.

Pitot Tube. A device for observing the velocity head of flowing water, consisting essentially of an orifice held to point up stream in flowing water and connected with a tube by which the rise of water in the tube above the water surface may be observed. It may be constructed with an up-stream and a down-stream orifice and two water columns, the difference of water levels being an index of the velocity head.

Plant Consumption. The water used by plants in the processes of growth. It includes that stored in the body of the plant and that dissipated from its leaf and body surfaces by transpiration.

Point Gage. A sharp-pointed rod attached to a graduated staff or vernier scale for measuring the elevation of the surface of flowing water. The point is lowered until the tip barely touches the water, forming a streak.

Porosity. (1) An index of the void characteristics of a soil or stratum as pertaining to percolation; degree of perviousness. (2) Ratio of void volume to total volume of a soil, or rock, generally expressed in percentages.

Potential Energy. Energy due to position. The potential energy of a given volume of immobile water with reference to any datum, is proportional to the product of its weight and the elevation of the center of gravity above that datum. The potential energy per unit of time of a given discharge with reference to any datum is proportional to the product of its weight per unit of time and the elevation of its hydraulic grade line above that datum.

Precipitation. The total measurable supply of water received directly from clouds, as rain, snow, and hail; usually expressed as depth in a day, month, or year, and designated as daily, monthly, or annual precipitation.

Pressure. Total load or force acting upon a surface; also appropriately used to indicate intensity of pressure or force per unit area.

Pressure Head. The head on any point in a conduit represented by the height of the hydraulic grade line above that point.

Priming. (1) The first filling of a canal reservoir, or other structure; that is, either the absolutely first, or the seasonally first. (2) Starting the flow, as in a pump or siphon.

Prism. The liquid mobile volume of a stream. The volume of a length of embankment or excavation.

Puddle. (1) Earthy material as a mixture of clay, sand, and gravel, placed with water to form a compact mass to reduce percolation. (2) To place such material.

Race. The channel that leads water to or from a water wheel; the former is "head race," the latter, "tail race."

Rack. A screen composed of parallel bars to catch floating debris.

Radial Gate. A pivoted gate whose face is usually a circular arc with center of curvature at the pivot. *See also* Taintor gate.

Rainfall. Precipitation in the form of water. Usage includes snow and hail in the term.

Ram. *See* Hydraulic ram.

Rapids. (1) A term used by some writers for "chute." (2) Swift and turbulent flow, without pronounced falls.

Rating. (1) The relation, usually determined experimentally, between two mutually dependent quantities, such as stage and discharge of a stream; current-meter vane revolutions, and water velocity, etc.; calibration. (2) The taking of measurements or the making of observations to establish a rating; calibrating.

Rating Curve (Table). A graphic (tabular) representation of a rating; a calibration.

Rating Flume. (1) An open conduit built in a channel to maintain a consistent regimen for the purpose of measuring the flow and developing stage-discharge relation. (2) A flume containing still water for rating current meters, Pitot tubes, etc.

Reach. A comparatively short length of a stream or channel.

Reconnaissance. A preliminary field examination of a proposed project.

Recorder. A device that makes a graph of the stage, pressure, depth, velocity, or the movement or position of water-controlling devices. *See also* Indicator; Register.

Recording Gage. *See* Water-level (stage) recorder.

Rectangular Weir. A measuring weir with a rectangular notch. Unless a suppressed weir is specified the term may be taken to mean a contracted weir.

Regimen. The condition of a stream and its channel as regards their stability. A river or canal is "in regimen" if its channel has reached a stable form as the result of its flow characteristics.

Register. (1) A device that notes quantities; it may make a graph or a printed or stamped record by figures or symbols on a dial or on an assembly of dials, indicate by pointer, index, or otherwise note such quantities as stage, pressure, velocity, depth, or quality; it may note the movement or position of water-controlling devices as gates or valves; a gage, indicator, or recorder. (2) To note such quantities. *See also* Indicator; Recorder.

Reservoir. A pond, lake, or basin, either natural or artificial, for the storage, regulation, and control of water.

Revolving Screen. A trash screen or rack in the form of a cylinder or as a belt between pulleys or rollers revolved mechanically or by the power of the water passing through it. The successive portions of the screen appearing above water are generally freed of trash by water jets, by automatic scrapers, or by an attendant.

Reynolds. *See* Critical velocity.

Ridging. Making small embankments or borders in fields to control irrigation water.

Riffle. Shallow rapids in an open stream, where the water surface is broken into waves by obstructions wholly or partly submerged.

Right Bank of a Stream. The right-hand bank when the observer is looking down stream.

Riparian. Pertaining to the banks of a body of water; a riparian owner is one who owns the banks; a riparian right is the right to control and use water by virtue of the ownership of the bank or banks.

Riprap. Broken stone placed on earth surfaces for their protection against the action of water; also applied to brush or pole mattresses, or brush and stone, or other similar materials used for protection.

Rock-Fill Dam. A dam composed of loose rock usually dumped in place; often with the up-stream part constructed of hand-placed, or derrick-placed, rock and faced with rolled earth or with an impervious surface of concrete, timber, or steel.

Rod-Float. A rod or staff designed to float in a practically vertical position for the purpose of observing velocities.

Roller-Gate. A hollow cylindrical gate with spur gears at each end meshing with an inclined rock anchored to a recess in the end pier or wall. It is raised or lowered by being rolled on the rack. It may close at a greater depth than its diameter by means of shields or aprons attached to the cylinder. *See also* Sector gate.

Rollway. The overflow portion of a dam; an overflow spillway.

Root Zone. That part of the soil invaded by the roots of plants.

Rotary Pump. A displacement pump for raising a liquid by the use of rotating elements instead of by pistons. It may operate at almost any speed, and does not depend on centrifugal forces to lift the water.

Rotation. A system of irrigation through which the irrigator receives his allotted quantity of water, not at a continuous rate, but as a large flow at stated intervals; for example, a number of irrigators receiving water from the same lateral may agree among themselves to rotate the water, each taking the entire flow in turn for a limited period.

Run-Off. The portion of precipitation that appears as flow in streams.

Run-Off Coefficient. The rate of run-off to precipitation.

Sag Pipe. A very appropriate term proposed as a substitute for "inverted siphon."

Sand-Trap. A device, often a simple enlargement, in a conduit for arresting the sand, silt, etc., carried by the water, and generally including means of ejecting them from the conduit.

Scouring Sluice. An opening in a dam controlled by a gate through which the accumulated silt, sand, and gravel may be ejected.

Second-Foot. A cubic foot per second.

Second-Foot-Day. The volume of water represented by a flow of 1 cu. ft. per sec. for 24 hr. It is 86,400 cu. ft., or nearly 2 acre-ft. (actually 1.9835); a convenient unit in storage computations.

Sector Gate. A roller type of gate in which the roller is a sector of a circle instead of a complete cylinder. *See also* Roller gate.

Seepage. The percolation of water through the soil; infiltration. Seepage from a canal or reservoir represents a loss that is conveniently expressed as a depth over the surface or wet perimeter in a given time. Seepage into a body is referred to as influent seepage; that away from a body, as effluent seepage.

Seiche. An oscillation of the water surface of a lake, probably due to unequal atmospheric pressure, or to wind, that sets the surface in vibration. The amplitude may amount to a foot or more, and the period may reach several hours.

Self-Mulching Soil. A soil that breaks up into fine, dry dust by cultivation, forming a mulch.

Semi-Arid. A term applied to a country or climate neither entirely arid nor strictly humid, but intermediate, with a shading to the arid side. A dry-farming country in which many crops grow without irrigation, but in which far better yields result from irrigation. The term "semi-humid" has a similar significance, with a shading toward the humid side.

Settling Basin. An enlargement in a conduit to permit the settlement of debris carried in suspension, usually provided with means of ejecting the material so collected; one form of sand trap.

Sharp-Crested Weir. A measuring weir with its crest at the up-stream edge or corner of a relatively thin plate, generally of metal.

Sheet-Piling. A diaphragm made up of meshing or interlocking members of wood, steel, concrete, etc., driven individually to form an obstruction to percolation, to prevent movement of material, for cofferdams, stabilization of foundations, etc.

Shooting Flow. *See* Supercritical flow.

Side Slopes. The slope of the sides of a canal, dam, or embankment; custom has sanctioned the naming of the horizontal distance first as 1.5 to 1 (or, frequently, $1\frac{1}{2} : 1$), meaning a horizontal distance of 1.5 ft. to 1 ft. vertical; a better form, not subject to misinterpretation by thoughtless transposition, is 1 on 1.5.

Side-Channel Spillway. *See* Lateral-flow spillway.

Silt. (1) Water-borne sediment. The term is generally confined to fine earth, sand, or mud, but is sometimes broadened to all material carried, including both suspended and bed load. (2) Deposits of water-borne material, as in a reservoir, on a delta, or on overflowed lands.

Sinuous Flow. *See* Turbulent flow.

Siphon. A closed conduit, a part of which rises above the hydraulic grade line. It utilizes atmospheric pressure to effect or control the flow of water through it. (An inverted siphon has none of the properties of a siphon—the term is a misnomer.) *See also* Sag pipe.

Skimming. Diverting surface water by shallow overflow to avoid diverting sand, silt, or other debris carried as bottom load.

Slope Gage. A staff gage placed on an incline and graduated to indicate vertical heights.

Sluice. (1) A conduit for carrying water at high velocity. (2) An opening in a structure for passing debris. (3) To cause water to flow at high velocities for wastage, for purposes of excavation, ejecting debris, etc.

Sluicing. Moving earth, sand, gravel, etc., by flowing water; hydraulic sluicing; colloquially, "hydraulicking."

Slush Ice. *See* Frazil ice.

Snow Course. A course laid out and permanently marked on the drainage basin of a stream, along which the snow is sampled at appropriate times to determine its depth and density for the purpose of forecasting subsequent run-off.

Snow Density. The water content of snow expressed as a percentage by volume. In snow surveys it is the ratio of the scale reading (inches of water) to the length of the snow sample, in inches.

Snow Sample. A core taken from the snow mantle on a snow course, by means of a sampling pipe, from which the depth and density may be determined.

Snow Sampler. An outfit consisting essentially of light jointed tubes for taking snow samples, and a spring scale graduated to read directly the corresponding depth of water contained in a snow sample.

Snow Surveys. A set of measurements of the depth and density of snow, usually made to determine the water stored on a drainage basin in the form of snow, as a means of forecasting the subsequent run-off.

Soil. Finely divided material composed of disintegrated rock mixed with organic matter; the loose surface material in which plants grow.

Soil Evaporation. Evaporation of water from moist soils.

SPECIFIC ENERGY. The energy of a stream referred to its bed; namely, depth plus velocity head of mean velocity.

SPECIFIC RETENTION. The ratio of the volume (or weight) of water which a soil will retain against the force of gravity (after having once been saturated) to its own volume (or weight).

SPECIFIC YIELD. Specific yield of a soil is the ratio of the volume (or weight) of water which it will yield to the force of gravity (after having once been saturated) to its own volume (or weight).

SPILLWAY. A passage for spilling surplus water; a wasteway.

SPUR DIKE. A dike of rock or other structure built from the bank into the channel for bank protection or for channel improvement.

STAFF GAGE. A graduated scale on a staff, plank, metal-plate pier, wall, etc., by which the elevation of the water surface may be read.

STAGE. The elevation of a water surface above its minimum; also above or below an established "low-water" plane; hence above or below any datum of reference; gage height.

STANDARD DEVIATION. A measure of the dispersion of a series of statistical values as precipitation, stream flow, etc.; it is the square root of the sum of the squares of the deviations from the mean, divided by the number of values or events in the series.

STANDING WAVE. A sudden rise in the water surface, generally fixed in position, such as a hydraulic jump; a standing wave may exist, however, where the principles of the hydraulic jump are not involved.

STAND-PIPE. A pipe or tank connected to a closed conduit and extending to or above the hydraulic grade line.

STATIC HEAD. The total head without deduction for velocity head or losses; for example, the difference in elevation of head water and tail water of a power plant.

STEADY FLOW. A constant flow; that is, the same volume in equal units of time.

STILLING-WELL. A pipe, chamber, or compartment with closed sides and bottom except for a comparatively small inlet or inlets communicating with a main body of water. Its purpose is to dampen waves or surges while permitting the water level within the well to rise and fall with the major fluctuations of the main body.

STOP LOG. A log, plank, cut timber, or steel or concrete slab or beam fitting into end guides between walls or piers to close an opening to the passage of water.

STREAM. A body of flowing water, whether in an open or closed conduit; a jet of water as from a nozzle; the term is incorrectly used to designate the conduit in which the stream flows.

STREAMING FLOW. *See* Subcritical flow.

STREAMLINE. *See* Laminar flow.

STRIPPING. Removing the top layer of soil containing vegetable matter or other undesirable material.

SUBCRITICAL FLOW. Flow at velocities less than one of the recognized critical values; specifically, turbulent flow with a mean velocity, less than Belanger's critical velocity; streaming flow.

SUBIRRIGATION. (1) Watering plants by applying the water below the ground surface. (2) Irrigation by the water table rising within or near the root zone, often under control. (3) Colloquially, "subbing."

SUBMERGED ORIFICE. An orifice which in use is drowned by having the tail water higher than all parts of the opening.

SUBMERGED WEIR. A weir which in use has the tail-water level equal to or higher than the weir crest.

SUBMERGENCE. The ratio of the tail-water elevation to the head-water elevation, when both are higher than the crest, the overflow crest of the structure being the datum of reference. The distances up stream or down stream from the crest at which head-water and tail-water elevations are measured are important but have not been standardized.

SUBSOIL. The material lying below the surface soil, generally devoid of humus or organic matter.

SUB-SURFACE FLOAT. A submerged body which is attached by a line to, and the movement of which is indicated by, a surface float; used for the purpose of observing velocities, or the direction of flow.

SUPERCRITICAL FLOW. Flow at velocities greater than one of the recognized critical values; specifically turbulent flow with a mean velocity equal to or greater than Belanger's critical; shooting flow; sinuous flow.

SUPPRESSED WEIR. A measuring weir notch whose sides are flush with the channel, thus eliminating (suppressing) end contractions of the overflowing water. A weir may be suppressed on one end, two ends, bottom, or any combination of them.

SURFACE CURVE. (1) The longitudinal profile assumed by the surface of a stream of water flowing in an open conduit; the surface curve is the curve of equilibrium of all forces acting on the flowing water. (2) The hydraulic grade line. *See also* Back-water curve; Drop-down curve.

SURFACE FLOAT. A float on a water surface used to indicate velocity or direction of flow.

SURFACE SLOPE. The inclination of the water surface expressed as change of elevation per unit of slope length; the sine of the angle which the water surface makes with the horizontal. The tangent of that angle is ordinarily used, no appreciable error resulting except for the steeper slopes.

TAIL RACE. A channel conducting water away from a water wheel; an afterbay.

TAIL WATER. The water immediately down stream from a structure.

TAINTOR GATE. A gate named from its inventor, Burnham Taintor. *See also* Radial gate.

TERRACES. (1) Sloping ground cut into a succession of benches and steep inclines for purposes of cultivation. Often the inclines are made quite steep and are protected by riprap, or retaining walls are substituted, thus giving greater areas for cultivation. (2) Areas bordered by low broad ridges constructed on cultivated land of such alignment, height, and spacing as to conform to the topography and to permit travel by cultivating and harvesting machinery, the object being to prevent loss of soil by erosion.

TEST PIT. An excavation to determine the nature of the material encountered or to disclose subsurface conditions.

TRANSITION. A short conduit uniting two others having different hydraulic elements; a conversion.

TRANSPIRATION. The process by which plants dissipate water from their leaf and body surfaces in the phenomena of growth. The water is brought to the surfaces of the plant body and there dissipated.

TRANSPIRATION RATIO. The ratio of the weight of water passed through a plant, to the weight of dry plant substance produced.

TRAPEZOIDAL WEIR. A contracted measuring weir with a trapezoidal notch. *See also* Cipolletti weir.

TRASH RACK. A grid or screen across a stream designed to catch floating debris.

TRAVELING SCREEN. (1) A diaphragm, usually of canvas in a frame moved by water in the direction of flow, for purposes of measuring directly the mean velocity; only useful in regular channels where the frame is shaped to the channel cross section and nearly fills it. (2) A revolving trash screen.

Triangular Weir. A contracted measuring weir notch with sides that form an angle with its apex downward; the crest is the apex of the angle; a V-notch weir.

Turbulence. A state of flow wherein the water is agitated by cross currents and eddies; opposed to a condition of flow that is quiet or quiescent.

Turbulent Flow. That type of flow in which any particle may move in any direction with respect to any other particle, and in which the head loss is approximately proportional to the second power of the velocity. (Sometimes designated as "sinuous flow" or "tortuous flow.")

Turbulent Velocity. That velocity above which, in a particular conduit, turbulent flow will always exist, and below which the flow may be either turbulent or laminar, depending on circumstances.

Underflow. (1) Movement of water through a previous subsurface stratum; the flow of percolating water; of water under ice, or under a structure. (2) The rate of flow or discharge of subsurface water.

Uniform Flow. A constant flow or discharge, the mean velocity of which is also constant. Uniform flow is also referred to as "steady uniform flow." It is an ideal condition that can only be approximated in fact. If the velocity of the constant discharge varies, the flow is defined as "steady-non-uniform."

Uniformity Coefficient (Hazen) (C_u). The ratio of D_{60} to D_{10} as determined in a mechanical analysis.

Uplift. The upward water pressure force on the base of a structure.

V-Notch Weir. *See* Triangular weir.

Vadose Water. (1) Water intermediate between soil water and fringe water. (2) Suspended water which may include all water in the soil from the water table to the ground surface.

Velocity Head. The distance a body must fall freely under the force of gravity to acquire the velocity it possesses. *See also* Kinetic energy.

Velocity of Approach. The mean velocity in the conduit immediately up stream from a weir, dam, Venturi throat, orifice, or other structure.

Velocity of Retreat. The mean velocity in the conduit immediately down stream from a structure.

Vena Contracta. The most contracted sectional area of a stream, jet, or nappe beyond the plane of the orifice or notch, through which it issues. *See also* Contraction.

Venturi Flume. A type of open flume with a contracted throat that causes a drop in the hydraulic grade line; used for measuring flow. *See also* Parshall measuring flume; Control flume.

Venturi Meter. A proprietary measuring device, consisting essentially of a Venturi tube and a special form of flow-registering device. Named after G. B. Venturi, an Italian physicist, and developed and patented by the late Clemens Herschel, Past-President and Hon. M. Am. Soc. C. E. *See also* Venturi tube, the generalized term for this apparatus.

Venturi Tube. A closed conduit which is gradually contracted to a throat causing a reduction of pressure head by which the velocity through the throat may be determined. The contraction is generally followed, but not necessarily so, by gradual enlargement to original size. Piezometers connected to the pipe above the contracting section and at the throat indicate the drop in the pressure head which is an index of flow.

Vertical-Velocity Curve. A graph of the relation between depth and velocity along a vertical line in a stream, as determined by a set of observations.

Wasteway. The channel required to convey water discharged into it from a spillway, escape, or sluice; a spillway.

Water Cushion. A pool of water maintained to take the impact of water overflowing a dam, chute, drop, or other spillway structure.

Water Demand. A schedule of the water requirements for a particular purpose, as for irrigation, power, municipal supply, plant transpiration, storage, etc.

Water Hammer. The phenomena of oscillations in the pressure of water in a closed conduit, resulting from checking the flow. Momentary pressure greatly in excess of the normal static pressure may be produced in this manner.

Water Level. A water surface; also its elevation above any datum; gage height; stage.

Water-Level (Stage) Recorder. A device for producing a graphic record of the rise and fall of a water surface with respect to time.

Waterlogged. A condition of lands where the ground water stands at a level that is detrimental to plants. It may result from over-irrigation or seepage with inadequate drainage.

Water Requirement. The total quantity of water, regardless of its source, required by crops for their normal growth under field conditions. *See also* Irrigation requirement.

Water Right. A legal right to the use of water.

Watershed. (1) The area drained by a stream or stream system. (2) The divide between drainage basins.

Water Spreading. The artificial application of water to lands for the purpose of storing it in the ground for subsequent withdrawal.

Water Table. The upper surface of a zone of saturation in soil or in permeable strata or beds.

Water Year. A special grouping of the periods of a year to facilitate water-supply studies. The United States Geological Survey uses October 1 to September 30.

Weep Holes. Openings left in retaining walls, aprons, linings, foundations, etc., to permit drainage, reduce pressures, etc.

Weir. A dam across a stream for diverting or for measuring the flow. *See also* Measuring weir.

Weir Head. (1) The distance from the crest of a weir (apex of a triangular weir) to the water surface in the forebay above the weir. It does not include the velocity head of the velocity of approach. (2) The energy head of the water referred to the crest of the weir, which does include the velocity head of the velocity of approach.

Wetted Perimeter. The length of the wetted contact between a stream of water and its containing conduit, measured along a plane at right angles to the direction of flow; that part of the periphery of the cross-sectional area of a stream in contact with its container.

Wicket Dam. A movable barrier made of wickets, or shutters, revolving about a central axis.

Wilting Coefficient. The moisture in percentage of dry weight remaining in the soil within the root as plants reach a condition of permanent wilting.

Wing Dam. A wall, crib, dike, row of piles, or other barrier projecting streamward from the shore; a spur dike.

Winter Irrigation. The irrigation of lands during the non-growing season in order to store water in the soil for subsequent use by plants; water spreading.

PIERS AND DOCKS *

BULKHEAD WALL. Name given in New York City to a retaining wall for a marginal wharf; the term is now common in other ports.

DOCK. An artificial basin for the use of vessels. "Dock" is often improperly applied to a pier, notably in New York City, and also to a marginal wharf.

DOCK WALL. A marginal wall on a wharf or pier.

DRY DOCK. A dock from which water can be excluded. It is generally used for repair or construction.

MARGINAL WHARF. A wharf parallel to the shore.

PIER. A wharf projecting from the shore.

QUAY. *See* Marginal wharf. "Quay" is common in Europe, but uncommon in the United States.

QUAY WALL. *See* Dock wall.

SEA WALL. *See* Bulkhead wall.

SLIP. Space between two piers; in some locations such spaces are called docks.

WET DOCK. A dock in which vessels remain afloat while loading and unloading. It is often provided with gates to retain water at low tide.

WHARF. A structure at which vessels may load and unload cargoes and passengers.

PLYWOOD †

ADHESIVE. A broader term than "glue," which ordinarily does not include the recently developed resin adhesives. Adhesion is defined as the "sticking together of substances in contact." *See also* Resin; Glue.

AGING OF PLYWOOD. A term used to designate the period, usually a matter of days, after the initial adhesive grip has become effective and until the joint has developed approximately its maximum strength and is suitable for testing.

ALL-VENEER CONSTRUCTION. Plywood without lumber cores, more frequently multi-ply for strength requirements, often 7-ply or 9-ply, to equal the thickness of conventional lumber-core plywood. The maximum thickness of any single sheet of veneer seldom exceeds $\frac{1}{4}$ in.

ANIMAL GLUE. *See* Glue.

BACK. Usually the rear or unexposed surface of a plywood sheet that requires normal strength but does not demand any selection for appearance. Should be reasonably equivalent to the face in thickness and strength.

BALANCED CONSTRUCTION. Plywood that has an equal amount of wood in each grain direction, and an odd number of plies, and is symmetrical on both sides of its center line.

BANDING OR RAILING. A strip of wood of any specified kind, extending around one or more sides of a lumber or all-veneer core, usually with a lengthwise grain. This banding facilitates shaping the edges, or it may be finished square to conceal the objectionable appearance of the pieces of the core and the crossbands. Designated thus: B 1S 2E = banded one side and two ends.

BLISTER (GLUING ERROR). A spot or area where the veneer does not adhere and bulges like a blister. It may be caused by lack of glue or adhesive or inadequate pressure. In hot pressing it may be caused by a pocket of steam, which often ruptures the veneer.

BOLE. The trunk of the tree.

BOND. The grip of the adhesive on the wood, at the line of its application. Used especially with heat-reactive resins. Cf. *setting* in glues.

CASEIN. *See* Glue.

CASSAVA. *See* Glue.

CAT EYES. Term used to describe small pin knots, less than $\frac{1}{4}$ in. in diameter.

COMPREGNATED WOOD (COMPREG.) (PREGWOOD) (JICWOOD). A consolidation of the terms, compressed-impregnated wood, referring usually to an assembly of layers of veneer impregnated with a liquid resin and bonded under very high pressures. More commonly, but not always, the veneer layers have parallel grain, i.e., laminated wood construction. "Jicwood" is the term used in England.

CORES OR CENTERS. A term usually applied to the central layer of plywood, which in lumber-core construction is the principal strength factor. It is also applied to veneer cores. The term is sometimes used in the Pacific Northwest to designate the layer that is spread with glue, which agrees with the above in 3-ply but is inconsistent when applied to 5-ply. Core also may refer to the remaining part of the log, too small to be cut into veneer on a lathe.

DOORS, PLYWOOD. Panel doors are those in which the stile and rail framework is thicker than the more central panels. Flush or slab doors are of uniform thickness with flat surfaces. Cores may be solid, of edge and end-glued lumber, or hollow.

EXTERIOR—DFPA. A grade designation of the Douglas Fir Plywood Association for plywood made with waterproof glue and intended for permanent exterior exposure.

FACE. The veneer on the exposed surface of the plywood.

FLEXWOOD. A trade name, describing cloth-backed thin veneer, for interior walls, especially plaster and masonry—applied much as wallpaper is hung.

GLUE. A term customarily applied to the older conventional cold-setting plywood adhesives, viz.:

Albumin, as now used for adhesive purposes, is more correctly called soluble dried blood. It is mixed cold and usually coagulated (set) under heat, but sometimes by chemical reagents. It is highly water-resistant, but little used. Blood is also used as an extender with other adhesives.

Animal glue is a derivative of bone and hide waste, usually prepared by cooking. Its application is best accomplished in a warm room and on warmed wood parts. It softens under moisture exposure and eventually becomes resoluble.

Casein is a dried-milk product, mixed cold with caustic, lime, and other ingredients. Its action on edge tools is

* Adapted from Greene, "Wharves and Piers," McGraw-Hill Book Co.

† Thomas D. Perry, "Modern Plywood," Pittman Publishing Corp.

abrasive, and it is partly resoluble on exposure to moisture.

Liquid glue is a prepared liquid adhesive or cement, usually sold at retail. Many types have fish by-products as their base. Not important in the plywood industry.

Resin adhesives, *see* Resin.

Soya-Bean meal is the residue of soya bean after the oil has been removed. It is mixed cold with caustic and other substances. It is the only glue that can be applied on wet veneers but is likely to stain delicately colored face veneers. It is a vegetable protein and, like casein, is only partly resoluble in water.

Vegetable glue is a starch product, usually with a cassava-root-flour base. It is prepared by cooking with caustic and cooled before use. It is widely used in the furniture and plywood industries as it gives an excellent bond dry, but it delaminates quickly under moisture exposure.

Glue Joint. That part of an aggregated wood product which comprises the adhesive (or glue) and the wood parts in contact therewith. Glue joint strength is measurable and is sometimes called bonding strength. *See* Bond.

High-Density Plywood. Plywood of special construction, made at high pressure, usually 500 lb. and up. With the increase in pressure comes a corresponding increase in density, or specific gravity.

Jicwood. *See* Compregnated wood.

Joint. The line between the edges or ends of two adjacent sheets of veneer or strips of lumber core, in the same plane. An edge joint is parallel to the grain of the wood, while a butt joint is at right angles thereto. Joint glue may be any type of glue or adhesive used to adhere these edges or ends together. The term is also applied to the surface on which layers of veneer and lumber are bonded together with adhesive. *See* Glue joint and Starved joint. An open joint occurs where there is a visible opening at the point of joining.

Lumber-Core Construction. As contrasted with all-veneer construction. The central layer is of lumber, usually edge-glued together from narrow (2- to 3-in.) strips. Lumber cores are seldom less than $\frac{3}{8}$ in. thick and give a lengthwise stiffness to the plywood, as well as a freedom from warp, that does not result from all-veneer construction.

Panel. Referring to a sheet or piece of plywood.

Ply. A sheet or layer of veneer.

PlyForm. A grade designation of the Douglas Fir Plywood Association, for concrete form plywood, made with highly water-resistant glue. Surfaces are mill-oiled and edge-sealed.

Plymetal. A term used to describe plywood that has metal sheets for one or more of the layers.

PlyPanel. A grade designation used by the Douglas Fir Plywood Association for sanded plywood, and further divided into good 2 sides, good 1 side, or sound 2 sides. It is intended to be exposed and finished on one or both sides but is not adapted to weather exposure.

PlyScord. A grade designation of the Douglas Fir Plywood Association for unsanded utility plywood that may contain certain defects that do not seriously affect strength and serviceability. One face is made tight by patching. Intended to be covered, and not for exposed finish or painting.

PlyWall. A grade designation used by the Douglas Fir Plywood Association for their wall-board grade. It has one side sound and the opposite side is permitted to have certain defects that do not affect strength or serviceability. It is slightly below PlyPanel in quality.

Plywood. An assembled product, made of layers of veneer and/or lumber and adhesive, the chief characteristic of which is the alternate cross layers, distributing the longitudinal wood strength. This product cannot be split, and shrinking and swelling, under the influence of moisture, are reduced to a minimum. Laminated wood has no cross layers.

Pregwood. *See* Compregnated wood.

Resin. A raw material, made synthetically, which is the basis for products called the plastics. Certain resins can be used to adhere pieces of wood, and these are called resin adhesives, less correctly resin glues. These adhesives are of relatively recent development and are much more durable than the older types of conventional glues.

Scarf. An angling joint, made either in veneer or plywood, where pieces are spliced or lapped together. The length of the scarf is usually 12 to 20 times the thickness. When properly made, scarf joints are as strong as the adjacent unspliced material.

Sheathing. Plywood used in the construction trades for the under covering of walls, roofs, or floors. Commonly grade marked "PlyScord" by the Douglas Fir Plywood Association.

Sheet. A single ply, or layer of veneer.

Shim. A long narrow patch, glued into the panel or into the lumber core.

Starved Joint. An expression used to indicate an inadequate amount of glue or adhesive, because of insufficient spread, too rapid absorption into the wood substance, or in some cases, with dense woods, of too much pressure.

Sunken Joint. A term describing small, straight depressions in the plywood surface, directly above the joints in the lumber core, or in the crossbanding. Caused by inadequate drying of the glue solvent before planing lumber cores, or by uneven thickness of the crossband veneer.

Superpressed Plywood. More correctly called high-density plywood.

Tego. The original and best known phenolformaldehyde resin film.

Two-Ply. A reinforced, veneer face construction in which fragile veneer, such as stump or burl, is reinforced by a $\frac{1}{40}$- to $\frac{1}{16}$-in. crosslaid backing veneer of birch or maple. It is usually bonded with a resin film and is primarily intended to prevent damage to fragile and costly veneer in handling.

Wall Board. Plywood used in the construction trades for wall covering that may have interior exposure.

Weldwood. Trade designation of the United States Plywood Corporation, applied to all their plywood. When branded "waterproof weldwood," the product is resin-bonded and suitable for exterior uses. Further designations, "aircraft" or "marine," indicate purposes for which such plywood may be used.

ROADS

Aggregate.* Natural or man-made material, such as crushed rock, gravel, sand, slag, and shell, used with or without artificial binder as material for the sub-base, base, or wearing course of a road. Aggregate in a surface course is often called road metal.

Base Course.* A layer of aggregate, treated soil, or soil-aggregate which rests upon the sub-base or natural foundation. The materials of the base course should usually be held together with a binder, but with certain materials good base courses may sometimes be made without the addition of an outside binder. The purpose of a base course is to furnish a compact, stable, and even surface on which to lay a wearing course.

Binder.* Binders include bituminous materials, portland cement, clay, ground limestone, ground shell, and other materials which tend to cement together the separate particles of road metal.

Bridge. A structure which provides a waterway or other opening under a road or highway and which has a clear span of 20 ft. or more between the inside faces of the end supports, measured normal to the face of the supports; or a multiple-span structure of which the sum of the individual clear spans plus the total width of the intermediate supports is in excess of 20 ft.

Course.* A layer of road material laid upon and parallel to the substructure or subgrade.

Crown.* The rise or difference in elevation between the top of the foreslope of a ditch or embankment and the center line of the roadway.

Culvert.* Any structure, not classified as a bridge, which provides a waterway or other opening under a road or highway.

Grade.* A line along the center of the road which, when viewed horizontally, defines the top-surface profile of a longitudinal section of the finished road.

Highway.† The entire improvement comprising the roadway and roadside development within the limits of the right-of-way.

Profile Grade.† The trace of a vertical plane intersecting the top surface of the proposed wearing surface, usually along the longitudinal center line of the roadbed. Profile grade means either elevation or gradient of such trace according to the context.

Right-of-Way.† The land secured and reserved to the public for highway purposes.

Road Metal.* Broken stone, gravel, slag, or similar material used in road surface or base construction or maintenance.

Roadbed.* That portion of the roadway which is included within the area and below the wearing surface and shoulders. Roadbeds are divided vertically into two general parts: the natural foundation and the road structure. The natural foundation is the non-manipulated natural ground upon which the road structure, placed directly upon it, depends for its support. The road structure may be made up of one of several parts. These parts, named from the natural foundation upward, are as follows: (*a*) substructure or subgrade, (*b*) sub-base, (*c*) base course, and (*d*) wearing course and shoulders.

Roadside.† The portion of the right-of-way not occupied by surface courses, curbs, paved gutters, or paved median areas. Where no surface courses are provided, the roadside shall include only such width or area of the roadbed as may be indicated on the plans.

Roadside Development.† The landscape development of the highway including landscape development of adjacent lands publicly owned or controlled.

Roadway.* That portion of the right-of-way included within the construction limits of the improvement.

Screen and Sieve.* In testing parlance as defined by the A.S.T.M., screens have round openings and sieves have square openings.

Shoulder.* The portion of a roadway between the edge of the metalled wearing course and the top of the foreslope of a ditch or embankment.

Side Ditch.* The open side drain adjacent to the roadbed, designed to carry water running to it from the roadway and adjacent side slopes.

Skew or Skew Angle.† The acute angle formed by the intersection of the line normal to the center line of the roadway with a line parallel to the face of the abutments, or, in the case of culverts, with the center line of the culverts.

Sub-Base.* A blanket or insulating course of aggregate laid one or more inches thick, with or without binder. The purpose of a sub-base is to resist the upward penetration of a plastic substructure into the base or wearing course above it.

Subgrade or Substructure.* Fill or embankment, or the upper surface of the natural foundation upon which a sub-base, base, or wearing course is laid.

Superstructure.† All that part of a bridge above the bridge seats, or above the spring line of arches, or above the bottoms of caps of timber trestles.

Wearing or Top Course.* A layer of treated or untreated road metal, well graded from coarse to fine, which rests upon the base course or on the natural foundation.

SEWERAGE WORKS ‡

A.B.C. Process (Alum, Blood, Clay). A method of deodorizing and precipitating sludge by the addition of alum, charcoal, or some other material, and clay, to the raw sewage. One of the earliest satisfactory methods of clarification by chemical precipitation.

Activated Sludge. Sludge settled out of sewage previously agitated in the presence of abundant atmospheric oxygen.

Activated-Sludge Method. *See* Activated-sludge process.

Activated-Sludge Process. Sewage treatment in which sewage standing in or flowing through a tank is brought into intimate

* From Am. Soc. C. E. "Military Roads in Forward Areas."
† From "Specifications for Construction of Roads and Bridges in National Forests and Parks" by P.R.A.
‡ From "Manual of Engineering Practice," Am. Soc. C. E.

contact with air and with biologically active sludge, previously produced by the same process. The effluent is subsequently clarified by sedimentation.

AERATION. The process or method of bringing about intimate contact between air and a liquid by allowing finely divided air to pass through the liquid or the finely divided liquid to pass through air.

AIR-LIFT. A device for raising sewage or other liquid by injecting air into and near the bottom of an open discharge pipe submerged in a well of the liquid to be raised.

ALIGNMENT. The direction of the axis of a sewer in plan.

ALTERNATING DEVICE. A device whereby sewage may be automatically delivered into different parallel treatment units in a cycle following a predetermined sequence.

APPURTENANCES. *See* Sewer appurtenances.

BACK-WATER GATE. A device for preventing the back flow of sewage or water.

BAFFLES. Deflectors of wood, metal, or masonry placed in flowing liquid to divert, guide, or agitate the flow of such liquid.

BAND SCREEN. An endless band or belt of wire mesh, bars, plates, or other screening medium, with passes around upper and lower rollers or guides.

BAR SCREEN. A screen composed of parallel bars or rods. *See also* Rack.

BARN SEWAGE. Wash water from stables, containing considerable quantities of animal wastes.

BASIN. A shallow tank, or natural or artificial depression through which liquids pass or in which they are detained for treatment.

BIO-AERATION. A modification of the activated-sludge process in which the sewage and sludge are agitated and aerated by mechanical means, such as paddle wheels or turbines.

BIOCHEMICAL ACTION. Chemical action resulting from the growth or metabolism of living organisms.

BIOCHEMICAL OXYGEN DEMAND. The quantity of oxygen required for biochemical oxidation in a given time at a given temperature, the determinations usually being for 5 days at 20° C.

BIOFILTRATION. The recirculation of sewage from a trickling filter to a settling tank preceding the filter. This process is covered by the Jenks patent.

BIOLYTIC TANK. A continuous flow tank with hopper bottom, with inlet arranged so as to agitate the sludge by the entry of sewage at the apex of the hopper-shaped bottom. This agitation tank is sometimes followed by a settling tank in which the sludge is detained until removed.

BLEACH (BLEACHING POWDER). Calcium hypochlorite.

BLOW-OFF. A waste gate or device for discharging accumulated solids or for emptying a depressed sewer.

BRANCH SEWER. An arbitrary term for a sewer which receives sewage from a relatively small area.

BRANCHES (JUNCTION PIECES). Special forms of vitrified tile and cast-iron pipe for making connections to a sewer. They are called Tee, Y, Tee-Y, Double-Y, and V, from their shapes.

BROAD IRRIGATION. The disposal of sewage by application to farm land, involving the incidental benefit to crops growing out of the irrigation and fertilization resulting from the application of the sewage. (Differs from sewage farming in that the primary purpose is the disposal of sewage while the raising of crops is incidental only.) *See also* Sewage farming.

CAGE SCREEN. A screen consisting of a cage, with sides of bars, rods, or mesh, so arranged that it may be lowered into the sewage and raised therefrom for cleaning.

CAPILLARY WATER. Water in the interstices of the soil or of a sand filter, which is not lost by draining.

CATCH BASIN. A chamber or well designed to prevent the admission of grit and detritus into a sewer.

CATCH PIT. *See* Grit catcher.

CATCHMENT AREA. The area of a watershed tributary to a lake, stream, or sewer.

CENTRIFUGE. A device in which sludge is dewatered by rapid rotation and automatically discharged.

CESSPOOL. A pit into which household sewage or other liquid waste is discharged and from which the liquid leaches into the surrounding soil or is otherwise removed.

CHAMBER. A general term for a space enclosed by walls or a compartment, often prefixed by a descriptive word as "grit chamber" or "screen chamber" indicating its contents, or "discharge chamber" or "flushing chamber" indicating its office.

CHEMICAL PRECIPITATION. Sedimentation accelerated by the coagulation of suspended or colloidal matter through the addition of chemicals.

CHLORINATION. Treatment with chlorine or bleaching powder for the purpose of disinfection, the retardation of decomposition, or the oxidation of organic matter.

CIRCUMFERENTIAL FLOW. Flow parallel to the periphery of a circular tank.

CLARIFICATION. The process of removing suspended and colloidal matter from a turbid liquid.

CLARIFIED SEWAGE. Loosely used for sewage from which suspended matter has been partly or completely removed.

COAGULATION. The flocculation of colloidal or suspended matter brought about by the addition of some chemical to the liquid, by contact, or by other means.

COARSE RACK. A relative term, but generally used when the clear space between bars is 2 in. or more.

COARSE SCREEN. A relative term, but generally used when openings are greater than 1 in. in least dimension, except in the case of racks. *See also* Coarse rack.

COARSE-GRAINED FILTER. General term for contact bed or trickling filter.

COEFFICIENT OF IMPERVIOUSNESS. The ratio, expressed decimally, of effectively impervious surface to the total catchment area.

COLLECTING SYSTEM. All sewers from the house to the outfall. *See also* Sewerage system.

COLLOIDAL MATTER. Colloids or matter colloidal in nature and action.

COLLOIDS. (1) The finely divided suspended matter which will not settle and the apparently dissolved matter which may be transformed into suspended matter by contact with solid surfaces or precipitated by chemical treatment. (2) Substances that are soluble as judged by ordinary physical tests but will not pass through a parchment membrane.

COMBINED SEWER. A sewer designed to receive both storm water and sewage.

COMBINED SYSTEM. A system of sewers, in which sewage and storm water are carried in the same conduits.

COMMERCIALLY DRY SLUDGE. Sludge containing not more than 10% of moisture by weight.

COMMON SEWER. A sewer in which all abutters have equal rights.

COMPARTMENT. A chamber in, or a division of, a structure for sewage treatment.

CONCENTRATED SEWAGE. A relative term. Sewage containing a relatively large quantity of organic matter.

CONDITIONING. *See* Sludge conditioning.

CONTACT AERATOR. A device consisting of a crate holding broken stone, coke, brushwood, or other media, which is placed in a single or two-story sedimentation tank and through which the sewage is made to flow upward and return on the outside and become activated by the admission of compressed air below.

Contact Bed. An artificial bed of coarse material, such as broken stone or clinkers, in a water-tight basin provided with controlled inlet and outlet. It is operated in cycles of filling with sewage, standing full in contact, emptying, and resting empty, in order to remove some of the suspended matter and oxidize organic matter by biochemical agencies.

Contaminated Water. Water unfit for any given use because of contact with or the presence of injurious substances.

Contamination. The introduction into water, otherwise satisfactory, of bacteria, sewage, or other substance, which makes it unfit for any given use.

Cover. *See* Manhole head.

Crown. The inside top of a sewer.

Crude Sewage. Sewage that has received no treatment.

Datum. Plane of reference for elevations.

Degreasing. The process of removing fats and greases from sewage, waste, or sludge.

Degree of Purification. A measure of the removal and oxidation of the objectionable or putrescible contents of sewage.

Depressed Sewage. A sewer, often crossing beneath a valley or a watercourse, which runs full or under greater than atmospheric pressure because its profile is depressed below the hydraulic grade line.

Detritus Tank or Chamber. A detention chamber larger than a grit chamber, usually with provision for removing the sediment without interrupting the flow of sewage; a settling tank of short detention period designed, primarily, to remove heavy settleable solids.

Diffuser. A porous plate or other device through which air is forced and enters the sewage in the form of minute bubbles.

Digestion. The biochemical decomposition of organic matter resulting in the formation of mineral and simpler organic compounds.

Dilute Sewage. Sewage containing a relatively small quantity of organic matter.

Dilution. (1) A method of disposing of sewage or effluent by discharging into a stream or other body of water. (2) The ratio of the volume of flow of a stream to the volume of sewage or effluent discharged into it.

Direct Oxidation Process. (So-called.) A proprietary method of treatment in which sewage previously dosed with lime is passed through closed tanks between plate electrodes across which electric current is passing while the liquid is agitated by rotating paddles.

Disk Screen. A screen in the form of a circular disk rotating about an axis perpendicular to its center.

Discharge Sewer. *See* Outlet pipe.

Disinfected Sewage. Crude sewage, or a sewage-plant effluent which has been treated with a disinfecting agent, commonly chlorine or "bleach," resulting in the destruction of bacteria sufficiently to reduce materially the danger of infection.

Disinfection. The partial destruction, ordinarily by the use of some chemical, of the micro-organisms likely to cause infection and disease.

Dispersion. A method of disposal of the suspended solids in sewage or effluent by scattering them widely in a stream or other body of water.

Distributor. A device used to apply sewage to the surface of a filter. There are two general types, fixed and movable. The fixed type may consist of perforated pipes or notched troughs, sloping boards, or sprinkler nozzles. The movable type may consist of rotating or reciprocating perforated pipes or troughs applying spray or a thin sheet of sewage.

Diversion Chamber. A chamber that contains a device for diverting all or a part of the flow.

Diversion Manhole. *See* Diversion chamber.

Domestic Sewage. Sewage derived principally from dwellings, business buildings, institutions, and the like. (It may or may not contain ground water, surface water, or storm water. It may also contain a small proportion of industrial waste liquid.)

Dorr Thickener (Clarifier). A proprietary device placed in a tank by which a system of scrapers, driven by a central shaft, revolves slowly, pushing the deposited sludge to a central outlet, from which it is removed by gravity or pumping.

Dortmund Tank. A vertical-flow sedimentation tank with hopper bottom. The sewage, introduced near the bottom, rises and overflows at the surface, and the sludge may be removed from the bottom before it becomes septic.

Dosing Chamber. *See* Dosing tank.

Dosing Siphon. An automatic siphon for discharging the contents of a dosing tank.

Dosing Tank. A tank into which raw or partly treated sewage is introduced and held until the desired quantity has been accumulated, after which it is discharged at such a rate as may be necessary for distribution essential to the subsequent treatment.

Drain. A conduit or pipe, usually underground, for carrying off, by gravity, liquids other than sewage and industrial wastes, and including ground or subsoil water, surface water, and storm water.

Drainage. A general term for gravity flow of liquids in conduits. Commonly applied to surface and ground water.

Drainage System. A system of drains.

Drainage Water. Water flowing in a drain derived from ground, surface, or storm water.

Drop Manhole. A shaft in which sewage falls from a sewer to a lower level.

Drum Screen. A screen in the form of a cylinder or truncated cone rotating on its axis.

Dry-Weather Flow. Flow of sewage in a sewer during dry weather.

Effective Size (Hazen) (D_{10}). The grain size on a mechanical analysis curve corresponding to $W\% = 10$.

Effluent. Sewage, partly or completely treated, flowing out of any sewage-treatment device.

Effluent Discharge Conduit. *See* Outlet pipe.

Ejector. *See* Pneumatic ejector.

Emscher Filter. *See* Contact aerator.

End Manhole. One at the up-stream end of a sewer.

Entrance Well. *See* Inlet well.

Evaporation. Vaporization of moisture from a wet surface.

Filtered Sewage. The effluent of a sewage filter.

Filtering Medium. The material through which sewage applied to a filter must pass.

Filtration. (1) The process of removing suspended and colloidal matter from a liquid and the oxidation of its dissolved organic matter, by causing it to flow through a relatively fine porous medium. (2) Sometimes loosely applied to the removal of solids and liquid organic matter in treatment beds.

Filtros. The trade name applied to an artificial porous stone made of carefully graded silicious sand by molding, pressing, firing, annealing, and grinding. It is used as a filtering medium and for diffusing air in the activated-sludge process.

Final Settling Basin. A tank through which the effluent of a trickling filter, or other oxidizing device, passes for the purpose of removing the settleable solids before its discharge.

Final Settling Tank. Same as final settling basin, but deeper and of less area.

Fine Rack. A relative term, but generally used when the clear space between the bars is 1 in. or less.

Fine Screen. A relative term, but generally used for a screen with openings $\frac{1}{4}$ in., or less, in least dimension.

Flaring Inlet. A funnel-shaped entrance to facilitate flow into a pipe or conduit.

Flotation. A method of collecting suspended matter in a tank as a scum at the surface by the evolution of gas by chemicals, electrolysis, heat, or bacterial decomposition.

Flowing-Through Chamber. The upper compartment of a two-story sedimentation tank.

Flush Tank. A chamber in which water or sewage is accumulated and discharged at intervals for flushing a sewer.

Flushing Chamber. *See* Flush tank; Flushing manhole.

Flushing Manhole. A manhole provided with a gate so that sewage or water may be accumulated and then discharged rapidly for flushing a sewer.

Frame. *See* Manhole head.

Fresh Sewage. Sewage of recent origin still containing free dissolved oxygen.

Gas Slot. *See* Gas vent.

Gas Vent. (1) A passage to permit the escape of gases of decomposition. (2) An opening which allows gas, liberated in an Imhoff tank sludge-digestion chamber, to reach the atmosphere without passing up through the sewage in the settling chamber.

Grade. Elevation of invert.

Gradient. *See* Slope.

Grating. A screen consisting of parallel bars, two sets being transverse to each other in the same plane.

Gravity System. A system in which all sewage runs on descending gradients from source to outlet, or where no pumping is required.

Grease Trap. A device by means of which the grease content of sewage is cooled and congealed so that it may be skimmed from the surface.

Grit. The heavy mineral matter contained in sewage, such as sand, gravel, cinders, etc.

Grit Catcher. A chamber usually placed at the upper end of a depressed sewer, or at other points of protection on combined or storm-water sewers, of such shape and dimensions as to reduce the velocity of flow and thus permit the settling out of grit.

Grit Chamber (Grit Compartment). A small detention chamber or an enlargement of a sewer designed to check the velocity of the sewage enough to permit the heaviest solid matter, such as grit, to be deposited with a view to its frequent and easy removal.

Ground Water. Water derived from beneath the surface of the ground.

Ground-Water Drain. A drain which carries away ground water.

Horizontal-Flow Tank. A tank or basin, with or without baffles, in which the direction of flow is generally horizontal.

House Connection. *See* House sewer.

House Sewage. (1) Sewage from dwellings. (2) Loosely used for domestic sewage.

House Sewer. A pipe conveying the sewage from a single building to a common sewer or point of immediate disposal.

Humus Sludge. (1) Digested sludge deposited in final or secondary settling tanks, following trickling filters or other oxidizing device. (2) Sludge resembling humus in appearance.

Humus Tank. A tank for collecting humus sludge. *See also* Final settling tank; Final settling basin.

Hydraulic Grade. The elevation of the surface of the liquid in a sewer above an assumed datum.

Hydraulic Gradient. The surface slope of the liquid in a sewer. Generally taken parallel to the invert.

Hydraulic Inclination. *See* Hydraulic gradient.

Hydraulic Slope. *See* Hydraulic gradient.

Hydrolysis. A change in the molecular composition of matter produced by the addition of water.

Hydrolytic Tank. In general, any sewage tank in which hydrolysis occurs, specifically applied to a special form of vertical-flow tank. General term for any sedimentation tank in which, by biochemical processes, a part of the suspended organic matter is liquefied and gasified.

Imhoff Tank. A deep two-storied tank invented by Karl Imhoff, M. Am. Soc. C. E., consisting of an upper or continuous sedimentation chamber and a lower or sludge-digestion chamber. The floor of the upper chamber slopes steeply to trapped slots, through which solids may settle into the lower chamber. The lower chamber receives no fresh sewage directly, but is provided with gas vents and with means for drawing digested sludge from near the bottom.

Industrial Sewage. Sewage in which industrial wastes predominate. *See also* Domestic sewage; Industrial wastes.

Industrial Wastes. Liquid wastes from industrial processes.

Infected Water. Water which contains pathogenic bacteria.

Infection of Water. The introduction of pathogenic bacteria into water in sufficient quantities to produce disease.

Infiltration. The leaching of water from the ground into a sewer.

Influent. Sewage, raw or partly treated, flowing into any sewage-treatment device.

Inlet. A connection between the surface of the ground and a sewer for the admission of surface or storm water.

Inlet Well. A well or opening at the surface of the ground to receive surface water which is thence conducted to a sewer.

Institutional Sewage. Domestic sewage from institutions, such as hospitals, sanitariums, or penal and charitable establishments.

Intercepting Sewer. A sewer which receives the dry-weather flow from a number of transverse sewers or outlets, with or without a determined quantity of storm water if from a combined system.

Intermittent Filter. A natural or artificial bed of sand or other fine-grained material to which sewage is intermittently applied in doses and through which it flows, opportunity being given for filtration and also oxidation of the organic matter by biochemical agencies.

Invert. Originally, the inverted arch of a masonry-lined sewer. By derivation, the floor, bottom, or lowest point in the internal cross section of a sewer.

Invert Block. A voussoir-shaped hollow tile built into the invert of a masonry sewer.

Inverted Siphon Sewer. *See* Depressed sewer.

Irrigation. *See* Subsurface irrigation; Surface irrigation; Broad irrigation; Sewage farming.

Junction Chamber. A converging section of a sewer used to facilitate the flow from one or more sewers into a main sewer.

Junction Manhole. A manhole at the junction of two or more sewers.

Kitchen Waste. Liquid culinary wastes.

Lamp Hole. A small vertical pipe or shaft leading from the surface of the ground to a sewer, for admitting a light for purposes of inspection.

Land Drain. A drain for drawing off water from land. *See also* Ground-water drain.

Lateral Sewer. A sewer which discharges into a branch or other sewer and has no other common sewer tributary to it.

Leaching Cesspool. A cesspool out of which the liquid leaches into the surrounding soil.

Line Manhole. A manhole in the line of a sewer at a point where no other sewers connect. It may be at a point where the sewer changes direction, either in line, slope, or grade.

LIQUID SLUDGE. Sludge containing sufficient water to permit it to flow by gravity (ordinarily above 80%).

MACLACHLAN PROCESS (a proprietary process). A method of conditioning sludge preparatory to dewatering by the application of sulfur dioxide gas.

MAIN SEWER. A sewer which receives one or more branch sewers as tributaries.

MANHOLE. A shaft, or chamber, from the surface of the ground to a sewer, large enough to enable a man to have access for the purpose of inspection and cleaning.

MANHOLE HEAD. The cast-iron fixture surmounting a manhole. It is made up of two parts: a frame, which rests on the masonry of the shaft, and a removable cover. Frames are either fixed or adjustable in height. Covers are "tight," "ventilated," or "anti-rattling."

MEDIUM SCREEN. A screen having openings intermediate between those of a coarse and a fine screen.

MESH SCREEN. A screen composed of woven fabric, usually of wire.

MILES ACID PROCESS. A proprietary method of treatment invented by George W. Miles, in which sewage is acidified by sulfurous acid fumes. The fumes are absorbed by a part of the sewage. This part is then mixed with the remainder of the sewage. Subsequent precipitation of solids results in clarification and a measure of disinfection.

OUTFALL SEWER. A sewer which receives the sewage from the collecting system and conducts it to a point of final discharge or to a disposal plant.

OUTLET PIPE. A pipe which conveys the effluent from a treatment plant to its final point of disposal.

OXIDATION. *See* Sewage oxidation.

OXIDIZED SEWAGE. Sewage in which the organic matter has been combined with oxygen and has become stable.

PERCOLATING FILTER. *See* Trickling filter.

PERCOLATION. The flow or trickling of a liquid downward through a relatively coarse filtering medium. The liquid usually does not fill the pores of the medium.

PLATE SCREEN. A screen composed of one or more perforated plates.

PNEUMATIC EJECTOR. A means of raising sewage, or other liquid, by alternately admitting it through a check valve into the bottom of a pot and then ejecting it through another check valve into the discharge pipe by admitting compressed air to the pot above the liquid.

POLARITE. Magnetic spongy carbon, formerly used as a filter medium after sedimentation.

POLLUTED WATER. Water made unclean or injured by sewage, industrial waste, or other substance.

POLLUTION. The act of making unclean or impure or the state of being unclean or impure as a result of admixtures of sewage, industrial wastes, or other substance.

PRECIPITATION. Rain and snowfall. *See also* Chemical precipitation.

PRIVATE SEWER. A sewer privately owned and used by one or more properties.

PUBLIC SEWER. A common sewer controlled by public authority.

PUTREFACTION. Biological decomposition of organic matter with the production of ill-smelling products. It occurs under conditions of oxygen deficiency.

PUTRESCIBILITY. (1) The susceptibility of waste waters, sewage, effluent, or sludge to putrefaction. (2) The relative tendency of organic matter to undergo decomposition in the absence of oxygen.

RACK. A screen composed of parallel bars, either vertical or inclined, from which the screenings may be raked.

RADIAL FLOW. Direction of flow across a circular tank, from center to periphery, or vice versa.

RADIAL INWARD FLOW. Inlet at periphery and outflow at the center of a circular tank.

RADIAL OUTWARD FLOW. Inlet at center and outflow at the periphery of a circular tank.

RAINFALL RATE. Precipitation, generally expressed in inches per hour.

RATE OF PRECIPITATION. *See* Rainfall rate.

RAW SEWAGE. *See* Crude sewage.

RECEIVING BASIN. *See* Inlet well.

REGULATOR. A device for controlling the quantity of sewage admitted to an intercepting sewer or unit of a disposal plant.

RELATIVE STABILITY. The ratio, expressed in percentage, of available oxygen in waste waters, sewage, effluent, or diluted sewage to that required to provide complete biochemical oxidation of the organic matters contained therein.

RELIEF SEWER. A sewer built to relieve an existing sewer of inadequate capacity.

RESERVOIR. A tank or basin primarily for storage of a liquid.

ROOF WATER. Storm water from roofs.

RUN-OFF. That part of the rainfall which reaches a stream, drain, or sewer.

RUN-OFF COEFFICIENT. The ratio, expressed decimally, of run-off to precipitation.

RUN-OFF RATE. An expression of the rate at which rainfall runs off from a surface, expressed in inches in depth of rainfall per hour, cubic feet per second, or other units.

SAND CATCHER. *See* Grit catcher.

SAND FILTER. A filter in which sand is the filtering medium. *See also* Intermittent filter.

SANITARY SEWAGE. (1) Domestic sewage with storm water excluded by design. (2) Sewage originating in the sanitary conveniences of a dwelling, business building, factory, or institution. (3) The water supply of a community after it has been used and discharged into a sewer.

SANITARY SEWER. A sewer which carries sewage and excludes storm, surface, and ground water.

SATURATION. The condition of a liquid when it has taken into solution the maximum possible quantity of a given substance at a given temperature and pressure, as water saturated with oxygen.

SCREEN. A device with openings, generally of uniform size, used to retain coarse sewage solids. The screening element may consist of parallel bars, rods, or wires, grating, wire mesh, or perforated plate, and the openings may be of any shape, generally circular or rectangular slots.

SCREENING. The removal of relatively coarse floating and suspended solids by straining through racks or screens made of bars, gratings, wires, or perforated plates.

SCREENINGS. Material removed from sewage by screens and racks.

SCUM. A mass of sewage solids, buoyed up by entrained gas, grease, or other substance, which floats at the surface of sewage.

SCUM BOARD. A vertical baffle dipping below the surface of sewage in a tank to prevent the passage of floating matter.

SECONDARY SETTLING TANK. *See* Final settling tank.

SEDIMENTATION. The subsidence and deposition of suspended matter in a liquid by gravity.

SEDIMENTATION TANK. A tank or basin in which sewage, partly treated sewage, or other liquid containing settleable solids is retained long enough, and in which the velocity is low enough, to bring about sedimentation of a part of the suspended matter, but without a sufficient detention period to produce anaerobic decomposition.

SEMICIRCUMFERENTIAL FLOW. Flow parallel to the semicircumferences of a circular tank, divided at the inlet and meeting again at the common outlet.

SEPARATE SLUDGE DIGESTION. The digestion of sludge in basins or tanks to which it is removed from the basins or tanks in which it originally settled.

SEPARATE SYSTEM. A system of sewers in which sewage and storm water are carried in separate conduits.

SEPT-AER-SED METHOD. Sewage treatment in which septic-tank effluent is aerated and passed into a sedimentation tank. The sludge from the sedimentation tank is then pumped back into the septic tank.

SEPTIC SEWAGE. Sewage undergoing putrefaction in the absence of oxygen.

SEPTIC TANK. A settling tank intended to retain the sludge in immediate contact with the sewage flowing through the tank for a sufficient period to secure a satisfactory decomposition of organic solids by anaerobic bacterial action.

SETTLEABLE SOLIDS. Suspended solids which will subside in quiescent sewage in a reasonable period. (Two hours is a common arbitrary period.)

SETTLED SEWAGE. Sewage from which some of the solids have settled out in a tank during quiescence or slow flow.

SETTLING CHAMBER. (1) The second or final element of the so-called biolytic tank. (2) Sometimes used to designate the sedimentation compartment of a two-story tank, as in the Imhoff tank. *See also* Sedimentation tank.

SETTLING SOLIDS. *See* Settleable solids.

SETTLING TANK. *See* Sedimentation tank.

SEWAGE. (1) Wash water and water-carried animal, culinary, and, in some cases, industrial wastes. (2) Liquid waste containing human excreta, and other matter, flowing in or from a house drainage system or sewer. Excreta include feces, urine, secretions from the skin, expectoration, etc. (3) Liquid wastes from dwellings and institutions, stables, and business buildings. It may also contain liquid wastes from industries. (4) A combination of (*a*) the liquid wastes conducted away from residences, business buildings, and institutions, and (*b*) those from industrial establishments, with (*c*) such ground, surface, and storm water as may be admitted to or find its way into the sewers. (5) The ordinary liquid contents of a sewer containing organic wastes, which may or may not include street wash.

SEWAGE DISPOSAL. General term. The act of disposing of sewage by any method.

SEWAGE FARMING. A term applied to the raising of crops where sewage is applied to the land for irrigation and fertilization purposes. *See also* Broad irrigation.

SEWAGE OXIDATION. The process whereby, through the agency of living organisms in the presence of oxygen, the organic matter is converted into a more stable or mineral form.

SEWAGE PURIFICATION. (1) The removal or mineralization of all putrescible organic matter and the removal of all infectious and offensive matter. (2) Loosely used for sewage treatment.

SEWAGE TREATMENT. Any artificial process to which sewage is subjected in order to remove or so alter its objectionable constituents as to render it less offensive or dangerous.

SEWAGE-TREATMENT WORKS. Treatment plant and means of disposal.

SEWER. A pipe or conduit, generally closed, but normally not flowing full, for carrying sewage and other waste liquids.

SEWER APPURTENANCES. Construction, devices, and appliances other than the pipe or conduit, which are appurtenant to a sewer, such as manholes, flush tanks, and surface inlets.

SEWER ARCH. The curved top of a masonry sewer.

SEWER DISTRICT. The area deemed benefited by the construction and use of sewers.

SEWER INLET. *See* Inlet well.

SEWER OUTFALL. The structure at the lower end of an outfall sewer.

SEWER TERRITORY. *See* Sewer district.

SEWERAGE SYSTEM. A collecting system of sewers and appurtenances.

SEWERAGE WORKS. Comprehensive term, including all construction for collection, transportation, pumping, treatment, and final disposition of sewage.

SEWERAGE-TREATMENT WORKS. *See* Sewage-Treatment Works.

SHEFFIELD SYSTEM. A method of activating sludge by the rotation of paddle wheels placed at intervals in a long and relatively narrow and shallow tank.

SIDE-WALLS. The vertical, curved, or inclined walls which support the arch or top of a masonry sewer.

SIMPLEX PROCESS. A process for activating sludge by the circulation of sewage up through a central tube, dispersing it by the rotation of an inverted cone suspended above, and permitting a downward return outside the tube.

SINK WATER. Liquid waste from a sink.

SKIMMING TANK. A chamber so arranged that floating matter rises and remains on the surface of the sewage until removed, while the liquid flows out continuously under partitions, curtain walls, or scum boards.

SLANT. A branch inserted in a sewer for the purpose of making connection thereto.

SLEEK. The thin oily film usually present which gives characteristic appearance to the surface of water into which sewage or oily waste is discharged.

SLOPE. The inclination of the invert of a sewer expressed in percentage of length, as a decimal, or as 1-ft. fall in a given length of feet.

SLOT. A narrow opening.

SLUDGE. The accumulated suspended solids of sewage deposited in tanks or basins, mixed with more or less water to form a semi-liquid mass.

SLUDGE BED. Natural or artificial layers of porous material upon which sludge is dried by drainage and evaporation.

SLUDGE CAKE. A mass resulting from sludge pressing or vacuum filtering.

SLUDGE CHAMBER. *See* Sludge-digestion chamber.

SLUDGE COMPARTMENT. *See* Sludge-digestion chamber.

SLUDGE CONCENTRATION. Any process of reducing the water content of sludge that leaves it still in a liquid condition.

SLUDGE CONDITIONING. Treatment of liquid sludge preliminary to, and to facilitate, dewatering.

SLUDGE DEWATERING. A general term for the removal of a part of the water in sludge by any process, such as draining, pressing, centrifuging, exhausting, passing between rollers, or acid flotation, with or without heat. It revolves reducing from a liquid to a spadable condition rather than merely changing the density of the liquid (concentration) on the one hand, or drying (as in a kiln) by high heat on the other.

SLUDGE DIGESTION. The biochemical process by which organic matter in sludge is gasified, liquefied, mineralized, or converted into more stable organic matter.

SLUDGE DRYING. The process of drying sludge by drainage or evaporation, by exposure to the air, or by application of heat.

SLUDGE PRESSING. The process of dewatering sludge by subjecting it to pressure, the solids being retained, usually by a cloth fabric through which the water passes.

SLUDGE-DIGESTION CHAMBER. (1) Any chamber used for the digestion of sludge. (2) The lower story of an Imhoff tank or Travis tank.

Sludge-Drying Bed. *See* Sludge bed.
Spadable Sludge. Sludge dry enough to be shoveled from the drying bed. (Ordinarily under 70% moisture.)
Spiral-Flow Tank. A tank used in carrying out the activated-sludge process in which a spiral motion is given to the sewage in its flow through the tank by the introduction of air through a line of diffusers placed on one side of the bottom.
Spray Nozzle. *See* Sprinkler nozzle.
Spraying Nozzle. *See* Sprinkler nozzle.
Sprinkler. *See* Sprinkler nozzle.
Sprinkler Nozzle. A nozzle used for applying sewage in the form of a spray to a trickling filter.
Sprinkling Filter. A trickling filter in which the sewage is applied by spray.
Squeegee. A device, generally with a soft rubber edge, used for dislodging and removing deposited sewage solids from the walls and bottoms of settling tanks.
Stability. The ability of any substance, such as sewage, effluent, or digested sludge, to resist putrefaction. (Antonym, putrescibility.)
Stable Effluent. A treated sewage that contains enough oxygen to satisfy its oxygen demand.
Stale Sewage. Sewage containing little or no oxygen, but as yet free from putrefaction.
Stench Trap. A flap in a frame which opens to admit cellar drainage to a sewer and then closes to prevent sewer air from entering the house.
Sterilization. The destruction of all micro-organisms ordinarily through the agency of heat or of some chemical.
Sterilized Sewage. A sewage effluent in which all micro-organisms have been destroyed.
Storm Drain. *See* Storm sewer.
Storm Overflow. A weir, orifice, or other device for permitting the discharge from a combined sewer of that part of the flow in excess of that which the sewer is designed to carry.
Storm Overflow Sewer. A sewer used to carry the excess of storm flow from a main or intercepting sewer to an independent outlet.
Storm Sewage. Liquid flowing in sewers during or following a period of rainfall and resulting therefrom.
Storm Sewer. A sewer which carries storm and surface water, street wash, and other wash waters, or drainage, but excludes sewage.
Storm Water. Excess water during rainfall or continuously following and resulting therefrom.
Storm-Water Drain. *See* Storm sewer.
Storm-Water Overflow. *See* Storm overflow.
Storm-Water Overflow Sewer. *See* Storm overflow sewer.
Street Sewer. Common sewer or public sewer in a street. *See also* Common sewer; Public sewer.
Strong Sewage. Sewage containing above the normal quantity of organic matter.
Subdrain. A drain built beneath a sewer to intercept ground-water and prevent it from entering the sewer, especially during construction.
Subgrade. The elevation of the bottom of a trench in which a sewer or drain is laid.
Submain Sewer. An arbitrary term for relatively large branch sewers.
Subsiding Basin. *See* Sedimentation tank.
Subsoil Drain. A land drain deep enough to take water from the subsoil.
Subsurface Irrigation. The process of sewage treatment in which sewage or effluent is applied to land by distributing it beneath the surface through open jointed pipes or drains.
Surface Inlet. *See* Inlet well.
Surface Irrigation. The process of sewage irrigation in which sewage is applied to and distributed over the surface of the ground.
Surface Water. Water which flows upon or over the surface of the ground.
Surface-Water Drain. A drain which carries surface water.
Suspended Matter. Solids physically usupended in sewage or effluent.
System of Sewerage. *See* Sewerage System.
System of Sewers. *See* Sewerage System.
Tank. Any artificial receptacle through which liquids pass or in which they are detained during collection or treatment.
Tight Cesspool. *See* Water-tight cesspool.
Tight Manhole Cover. A manhole cover without openings.
Trade Wastes. British expression for industrial wastes. *See* Industrial wastes.
Trap. A device to prevent sewer air from backing up and escaping through a plumbing fixture. When made of cast iron or vitrified tile, it may be of various forms defined as running trap, P-trap, S-trap, etc.
Trash. The material removed from combined and storm-water sewers by coarse racks.
Travis Tank. A two-story hydrolytic or septic tank invented by Dr. Travis, consisting of an upper sedimentation chamber with steeply sloping bottom terminating in slots through which the deposited solids pass into a lower or sludge-digestion chamber through which a predetermined part of the sewage is allowed to pass for the purpose of seeding and maintaining bacterial life in the sludge and carrying away decomposition products. This is for the purpose of inducing digestion of the sludge attended by its reduction in volume.
Treated Sewage. Sewage which has received more or less complete treatment.
Trickling Filter. An artificial bed of coarse material, such as broken stone, clinkers, slate, slats, or brush, over which sewage is distributed and applied in drops, films, or spray, from troughs or drippers, moving distributors, or fixed nozzles, and through which it trickles to the underdrains, giving opportunity for organic matter to be oxidized by biochemical agencies.
Trunk Sewer. A sewer which receives many tributary branches and serves as an outlet for a large territory. *See also* Main sewer.
Twin or Multiple Dosing Tanks. Twin or multiple tanks of equal capacity, each equipped with a dosing device, which devices are usually so interconnected that they fill and discharge alternately, or in rotation.
Underdrain. A land drain laid below the surface of the ground, or of a sand filter or sludge bed. *See also* Subdrain.
Uniformity Coefficient (Hazen) (*Cu*). The ratio of D_{60} to D_{10} as determined in a mechanical analysis.
Ventilated Manhole Cover. A manhole cover with openings.
Vertical Flow Tank. A sedimentation tank in which the sewage enters near the bottom, rises vertically, and flows out at the top.
Water-Tight Cesspool. A cesspool with tight walls to prevent leaching and from which the contents are removed at intervals.
Weak Sewage. *See* Dilute sewage.
Wing Screen. A screen in which the screening elements are radial planes or curved vanes rotating on a horizontal axis.

SOILS

ADOBE. Heavy-textured sand; sandy silt; sandy silty clay; alluvial clay—southwestern United States and Mexico.

ANGLE OF INTERNAL FRICTION (ϕ) $\tan \phi = \frac{s-c}{W}$, where W = normal pressure, s = shear strength (under W pressure), c = cohesive strength (shearing strength without pressure).

BEACH SAND. Uniform, rounded grain sand. Highly stable when wet but unstable when dry, such as Daytona Beach sands.

BINDER. The fine soil (clay) fraction inherent in or added to sands and gravels for cohesion; soil fraction passing No. 40 sieve; also admixture for stabilizing.

BLOW SAND. Wind-borne, free-moving dune sand.

CALCAREOUS. Containing an appreciable content of calcium carbonate, usually from limestone. "Calcareous" is applied to soils and gravels.

CALICHE. Cemented mixture of sand, clay, and gravel, soft limestone—southwestern United States.

CENTRIFUGE MOISTURE EQUIVALENT (w_{cme}).* (In most uses the abbreviation C.M.E. may be used. When, as rarely, a symbol is desired, w_{cme} should be used.) The water content retained by a soil which has been first saturated with water and then subjected to a force equal to 1,000 times the force of gravity for 1 hr.

CHALK. Dry porous lime rock.

CHERT. Fine-grained, dense-textured, gray, white, or black rock—southern United States.

CLAY, HARD. Clay that must be excavated with pick and cannot be remolded in fingers.

CLAY, MEDIUM. Clay that can be excavated with spade and remolded with difficulty

CLAY, SOFT. Clay that can be excavated with shovel and easily remolded in fingers.

COMPACTION, DEGREE OF (D_d).* (Also called degree of density.) Defined by the equation

$$D_d = \frac{\text{(Void ratio of sample)} - \text{(Void ratio in densest state)}}{\text{(Void ratio in loosest state)} - \text{(Void ratio in densest state)}}$$

CONSISTENCY INDEX (I_c).* The ratio of the difference between the liquid limit and the natural water content to the difference between the liquid limit and the plastic limit. Defined by the equation

$$I_c = \frac{w_L - w}{I_p}$$

COQUINA. Marine shells firmly cemented together—Florida.

CORAL. Calcareous, rocklike material formed by secretions of marine organisms—tropical areas.

DENSITY, DEGREE OF.* *See* Compaction, degree of.

DIAMETER, GRAIN (D).* (Also called grain size, or particle size.) The size of grain, usually in millimeters, as determined by sieve analysis or wet mechanical analysis; hence not a true grain size except for spherical grains.

DISINTEGRATED GRANITE. Granular soil derived from advanced weathering and disintegration of granite rock.

DUST. Fine, dry, pulverized soil particles that can be lifted and carried by wind.

EFFECTIVE SIZE (HAZEN) (D_{10}).* The grain size on a mechanical analysis curve corresponding to $W\% = 10$.

EQUIVALENT VOLUMETRIC CHANGE.* *See* Volumetric shrinkage limit.

FIELD MOISTURE EQUIVALENT (w_{fme}).* (In most uses the abbreviation F.M.E. may be used. When, as rarely, a symbol is desired, w_{fme} should be used.) The minimum water content at which a drop of water placed on a smoothed surface of a soil will not immediately be absorbed by the soil but will spread over the surface and give it a shiny appearance.

FINES. Commonly the binder of silt and clay passing a No. 200 mesh sieve in a soil.

FLOCCULATION LIMIT (w_f).* The water content of a soil when it is in the condition of a deflocculated sediment.

FLOCCULATION RATIO (e_f).* The void ratio of a soil when it is in the condition of a deflocculated sediment.

FLOW INDEX (I_f).* The slope of the flow curve. The flow curve is the locus of points obtained from a standard liquid limit test and plotted on a graph representing water content as ordinates on an arithemtic scale and the number of blows as abscissas on a logarithmic scale. Thus the flow index is numerically equal to the difference between the water content at 10 and at 100 blows, or at 1 and at 10 blows.

FROST BOILS. Soil approaching a liquid condition from melting ice lenses erupting in surface failures.

FROST HEAVE. Lifting of soil caused by accumulation of ice lenses.

GRAVEL, PIT OR BANK RUN. Natural gravel deposits, may contain sand, clay, or silt.

GUMBO. Dark-colored, very sticky, highly plastic clay. Fine-grained, devoid of sand, impervious, waxy, and soapy in appearance and feel—central and southern United States.

HARDPAN (PAN). (Loosely used). Very dense mass of clay, sand, and gravel that must be excavated with a pick; glacial clay; any hard stratum difficult to excavate.

HYDROSTATIC PRESSURE RATIO (K).* A term used in earth-pressure computations to represent the ratio between the normal component of pressure at a point on a given plane and the pressure which would exist at the same point in a liquid of the same unit weight. Thus $p_n = K\gamma_m H$.

KAOLIN. Pure white clay as found in Florida and China. Kaolin is an ideal binder.

LINEAL EXPANSION (L_E).* The increase in one dimension, expressed as a percentage of that dimension at the shrinkage limit, of a soil mass when the water content is increased from the shrinkage limit to any given water content.

LINEAL-EXPANSION LIMIT (L_{LE}).* The increase in one dimension, expressed as a percentage of that dimension at the shrinkage limit, of a soil mass when the water content is increased from the shrinkage limit to the field moisture equivalent.

LINEAL SHRINKAGE (L_S).* The decrease in one dimension, expressed as a percentage of that dimension originally, of a soil mass when the water content is reduced from the original percentage to the shrinkage limit.

LINEAL SHRINKAGE LIMIT (L_{LS}).* The decrease in one dimension, expressed as a percentage of that dimension at the field moisture equivalent, of a soil mass when the water content is reduced from the field moisture equivalent to the shrinkage limit.

LIQUID LIMIT (w_L).* (in most cases the abbreviation L.L. may be used. When, as rarely, a symbol is desired, w_L should be used.) The upper limit of the plastic state, expressed as the water content at which the flow (*see* Flow Index) intersects the "25 blows" ordinate.

LOAM. In some localities a friable mixture of sand, clay, and silt. In other localities an organic topsoil suitable for cultivation and plant growth.

* Am. Soc. C. E., "Soil Mechanics Nomenclature."

LOESS. Windblown, pale-colored silt and clay, very porous and cavitated. It is characterized by thick beds and vertical cleavage. Cut slopes usually stand vertical—central United States and China.

MARL. Quartz clay, calcite, and sand; indefinite term for any earthy crumbling deposit; sticky calcareous clays, silts, and fine sands.

MICACEOUS. Containing sufficient mica flakes to give a distinctive appearance. "Micaceous" is applied to soils and clays.

MOISTURE CONTENT.* *See* Water content.

MOISTURE INDEX (I_w).* The ratio of the plasticity index to the difference between the natural water content and the plastic limit, expressed by the equation

$$I_w = \frac{I_p}{w - w_p}$$

MUD (MIRE). Slimy or pasty mixture of earth or volcanic ash and water.

MUSKEG. A peat bog; a depression filled with peat or organic deposits—Canada and Alaska.

OVERBURDEN. The soil mantle found directly over a deposit of rock, sand, or gravel. Either stripped off or broken down for mixing as a binder.

PER CENT FINER ($W\%$).* The ordinate of the mechanical analysis curve, representing, for a given soil, the percentage of particles by weight having diameters smaller than the value of D corresponding to $W\%$.

PERMEABILITY, COEFFICIENT OF (k).* The discharge velocity of flow of a fluid through a porous mass under a unit hydraulic gradient. Thus in Darcy's equation, $k = \frac{V}{At}$, in which A is the gross area of the soil mass.

PLASTIC LIMIT (w_p).* (In most cases the abbreviation P.L. may be used. When, as rarely, a symbol is desired, w_p should be used.) The lower limit of the plastic state, expressed as the minimum water content at which a soil can be rolled into a thread $\frac{1}{8}$ in. in diameter without crumbling.

PLASTICITY INDEX (I_p).* (In most cases the abbreviation P.I. may be used. When, as rarely, a symbol is desired, I_p should be used). The numerical difference between the water content at the liquid limit and the water content at the plastic limit. $I_p = W_L - W_p$.

POROSITY (n).* The ratio, expressed as a percentage, of the intergranular space in a given soil mass to the total volume of the soil mass. Porosity must be clearly differentiated from void ratio, e. The relation between the two terms is expressed by the equation $n = e/(1 + e)$.

QUICKSAND. (A condition, not a soil type.) Any fine granular soil carrying water under a head. Quicksand flows into an excavation. Any applied load will rapidly sink.

RED DOG. Residue of burned coal dumps. (Colloquial United States term.)

REMOLDING INDEX (I_R).* The ratio of the modulus of elasticity (or deformation) of a soil in the undisturbed state to the modulus of elasticity (or deformation) of the soil in the remolded state.

SAND CLAY. An intimate mixture of sand and clay about 12–18% clay, 5–15% silt, 65–80% sand; the natural topsoil.

SATURATION, DEGREE OF (S).* The ratio, expressed as a percentage, of the volume of water in a given soil mass to the total volume of intergranular space (voids). Thus $S = (V_w/V_v) \times 100$.

* Am. Soc. C. E., "Soil Mechanics Nomenclature."

SCORIA. Lava with numerous cavities—western United States; particles of volcanic origin.

SHALE. Firm, laminated, platy, stratified clay minerals. Shale is plastic when wet and disturbed.

SHINGLE. Rounded, waterworn gravel pebbles and stone without sand.

SHRINKAGE LIMIT (w_s).* In most cases the abbreviation S.L. may be used. When, as rarely, a symbol is desired, w_s should be used.) The maximum water content at which a reduction in water content will not cause a decrease in volume of the soil mass.

SHRINKAGE RATIO (R_s).* (In most cases the abbreviation S.R. may be used. When, as rarely, a symbol is desired, R_s should be used.) The ratio between a given volume change, expressed as a percentage of the dry volume, and the corresponding change in water content above the shrinkage limit, expressed as a percentage of the weight of the oven-dried soil.

SILICA. Hard crystalline silicon dioxide; the principal constituent of quartz and sand.

SILICEOUS. Containing silica.

SLIME. Soft, moist, adhesive mud or earth.

SLURRY (SLIP). A watery mixture of soil and water that will just flow.

SOIL MORTAR. Soil fraction in mixtures passing a No. 10 sieve.

SPECIFIC GRAVITY (G).* The ratio of the weight in air of a given volume of a material at a stated temperature to the weight in air of an equal volume of distilled water at a stated temperature, usually 4° C.

SYMBOLS. The following alphabetical list is taken from the Am. Soc. C. E. Manual 22. It is for the use of readers of soil mechanics literature who desire to find the term represented by a given symbol. The table may also be used by writers to determine the uses, if any, recommended for a given symbol when it becomes necessary for him to select a symbol for a term not included in the list.

SYMBOL	TERM
A	= area.
a_v	= compressibility, coefficient of.
b	= breadth or width.
C	= cohesion, resultant or total.
C_c	= compression index.
C_s	= swelling index.
C_u	= uniformity coefficient (Hazen).
c	= cohesion per unit area.
c_v	= consolidation, coefficient of.
D	= diameter; grain diameter.
D_{10}	= effective size (Hazen).
D_d	= density, degree of; compaction, degree of.
E	= modulus of elasticity.
e	= base of natural logarithms; void ratio.
e_c	= void ratio, critical.
e_0	= void ratio at pressure p_0 on the compression curve
e_f	= flocculation ratio.
e_s	= void ratio at pressure p_0 on the swelling curve.
F	= force, total internal.
F_n	= normal component of F.
F_t	= tangential (shearing) component of F.
f	= force per unit area; stress per unit area, internal.
f_n	= normal component of f.
f_t	= tangential (shearing) component of f.
$\overline{F}$	= effective force, total internal.
$\overline{F}_n$	= normal component of $\overline{F}$.
$\overline{F}_t$	= tangential (shearing) component of F.

SYMBOL	TERM
f	= effective force per unit area; effective stress per unit area, internal.
$\bar{f}_n$	= normal component of f.
$\bar{f}_t$	= tangential (shearing) component of $\bar{f}$.
G	= specific gravity.
g	= gravity, acceleration of.
H	= height, depth, or thickness.
H_s	= reduced height.
I	= modulus of incompressibility.
I_c	= consistency index.
I_f	= flow index.
I_p	= plasticity index.
I_R	= remolding index.
I_T	= toughness index.
I_w	= moisture index.
i	= hydraulic gradient.
J	= seepage force, resultant.
j	= seepage force per unit volume.
K	= hydrostatic pressure ratio.
k	= permeability, coefficient of.
L	= distance, or length.
L_E	= lineal expansion.
L_{LE}	= lineal expansion limit.
L_{LS}	= lineal shrinkage limit.
L_S	= lineal shrinkage.
m	= perimeter shear.
n	= porosity; developed pressure.
P	= force, total; load, total.
P_A	= earth pressure, total active.
P_P	= earth pressure, total passive.
p	= force per unit area; load per unit area.
Q	= discharge, rate of; resistance, total or resultant.
q	= discharge, rate of, per unit length or per unit area; resistance per unit area or length.
q_0	= ultimate bearing capacity per unit area at ground surface.
q_r	= compressive strength per unit area (triaxial).
q_s	= shear strength per unit area.
q_u	= compressive strength per unit area (unconfined test).
R	= reading.
R_s	= shrinkage ratio.
r	= radius.
S	= hydraulic gradient; saturation, degree of.
s	= shear strength per unit area.
T	= temperature.
T_v	= time factor.
t	= time.
U	= neutral force.
$U\%$	= consolidation, per cent of.
u	= hydrostatic excess pressure.
u_w	= neutral pressure per unit area.
u_z	= hydrostatic pressure.
V	= volume.
V_S	= volumetric shrinkage.
V_{SL}	= volumetric shrinkage limit.
v	= velocity.
W	= weight or load, total.
$W\%$	= per cent finer in mechanical analysis plot.
w	= water content (moisture content).
w_{cme}	= centrifuge moisture equivalent.
w_f	= flocculation limit
w_{fme}	= field moisture equivalent.

* Am. Soc. C. E., "Soil Mechanics Nomenclature."

SYMBOL	TERM
w_L	= liquid limit.
w_0	= water content, optimum.
w_p	= plastic limit.
w_s	= shrinkage limit.
α	= angle.
β	= angle.
γ	= unit weight.
γ_w	= unit weight of water, equal to 1 in the metric system.
δ	= displacement; or total deformation.
$\left.\begin{matrix}\delta_x\\ \delta_y\\ \delta_z\end{matrix}\right\}$	= components of δ.
ϵ	= base of natural logarithms; deformation per unit length; strain.
ζ	= component of ρ in Z-direction.
η	= component of ρ in Y-direction.
θ	= angle.
μ	= coefficient of absolute viscosity.
ν	= coefficient of kinematic viscosity; concentration factor.
ξ	= component of ρ in x-direction.
ρ	= displacement; deformation, total.
$\left.\begin{matrix}\rho_x\\ \rho_y\\ \rho_z\end{matrix}\right\}$	= components of ρ.
σ	= normal component of internal force per unit area (normal component of stress).
$\bar{\sigma}$	= normal component of effective internal force per unit area (normal component of stress).
τ	= tangential component of internal force per unit area (tangential component of stress).
$\bar{\tau}$	= tangential component of effective internal force per unit area (tangential component of effective stress).
ϕ	= angle of internal friction.
ψ	= angle.

SUGAR SAND. Loose, cohesionless sand of uniform grain size resembling granulated sugar. (Colloquial.)

TILL. Glacial deposits of unsorted material ranging from fine clay to large boulders.

TOPSOIL. Commonly, organic surface soil suitable for cultivation—southeastern United States; a weathered mixture of sand clay and silt (sand-clay), such as the topsoils of Georgia and the Carolinas. Used for road and airport building.

TOUGHNESS INDEX (I_T).* (In most cases the abbreviation T.I. may be used. When, as rarely, a symbol is desired, I_T should be used.) The ratio of the plasticity index to the flow index. Thus $I_T = I_p I_f$.

UNIFORMITY COEFFICIENT (HAZEN) (C_u).* The ratio of D_{60} to D_{10} as determined in a mechanical analysis.

UNIT WEIGHT (2).* Weight per unit volume, such as grams per cubic centimeter and pounds per cubic foot.

VOID RATIO (e).* The ratio of the volume of intergranular space to the volume of solid particles in a given soil mass without regard to the proportions of liquid, air, or gas which may occupy the space.

VOID RATIO, CRITICAL (e_c).* The void ratio of a cohesionless soil at which continuous shearing deformation can take place without change in void ratio.

VOLUMETRIC CHANGE.* *See* Volumetric shrinkage.

Volumetric Shrinkage (V_S).* (Also called volumetric change.) The decrease in volume, expressed as a percentage of the dry volume, of a soil mass, when the water content is reduced from a given percentage to the shrinkage limit.

Volumetric-Shrinkage Limit (V_{SL}).* The decrease in volume, expressed as a percentage of the dry volume, of a soil mass when the water content is reduced from the field moisture equivalent to the shrinkage limit.

Water Content (w).* The ratio, expressed as a percentage, of the weight of water in a given soil mass to the weight of solid particles.

Water Content, Optimum (w_o).* The water content at which the maximum density is produced in a soil by a specific amount of compaction.

STEEL †

Adhesion. The force which holds together two bodies placed in close contact with each other.

Alloy. A substance consisting of two or more metals mixed together, or non-metallic bodies mixed with metals, in intimate solution or combination with one another, forming, when melted, a homogeneous fluid.

Aluminum. A white metal with high tensile strength and low specific gravity—used for purifying steel.

Amorphous. Without regard for definite form; uncrystallized; structureless.

Anchor Arm. The end portion of a cantilever bridge extending from one of the main piers to an anchor pier.

Anchorage. A device for anchoring down any part subjected to to uplift, such as the end of the anchor arm of a cantilever bridge.

Angle. The amount of divergence between two intersecting straight lines. The term is also applied to an angle-iron section.

Bulb angle. An angle-iron section in which one leg has a bulb on one end.

Clip angle. A short attaching angle that takes a portion of the stress of any member; also termed a "lug angle."

Connection angle. An angle iron used for connecting two pieces.

Flange angle. One of the upper or lower chord angles in a girder.

Flashing angle. An angle to which flashing is attached.

Lacing or lattice angle. An angle used in latticing.

Lug angle. A clip angle.

Seat angle. A short angle riveted to a column to support temporarily a beam during erection.

Shelf angle. A seat angle.

Starred angles. A pair of angles placed corner to corner with legs outstanding and held in position by tie-plates riveted thereto at intervals.

Stiffening angles. Angles riveted to the web of a girder to stiffen it against buckling.

Thrust angle. A short angle inserted between the outstanding legs of a column at the bottom of the cantilever bracket to carry the thrust from the latter to the cross girder; an angle member in traction bracing.

Angle Clip. A clip angle.

Angle Iron. A rolled piece of steel having a cross section shaped into a right angle.

Angle Lug. A clip angle.

Angle of Twist. An angle of Torsion. *See* Torsion.

Angular Strain. A torsional strain. *See* Strain.

Anneal. To reduce the brittleness and increase the ductility of metal by heating to a certain temperature, then cooling slowly in air or oil.

Apex. The intersection of a web member with a chord or flange; also called a panel point.

Approach. The construction leading to the end of a bridge.

Apron. A device to protect a river bank or river bed against scour; a shield.

Ice apron. An ice breaker, or starling, placed on the upstream end of a bridge pier to protect it from the moving ice.

Arc. A portion of a curve; an arch.

Arch. Any bowlike curve, structure, or object, usually having the convex side upward, generally spanning an opening and producing horizontal as well as vertical reactions.

Blind arch. An arch in which the opening is walled up.

Braced arch. An openwork truss in the form of an arch.

Catenary arch. An arch that takes the form of an inverted catenary.

Circular arch. An arch that takes the form of a portion of a circle.

Crown thrust of an arch. The thrust or compression existing at the crown of an arch due to the loading.

Elastic arch. An arch designed on the basis of the elastic theory of materials.

Elliptical arch. An arch having the form of a semi-ellipse.

Geostatic arch. An arch which has a curve of such nature that the vertical pressure is proportional to the depth below a fixed horizontal plane, and the horizontal pressure bears to the vertical pressure a fixed ratio depending on the nature of the superincumbent materials.

Hinged arch. An arch that has one or more hinged joints.

Inverted arch. An arch having its intrados below the axis or springing line.

Lenticular arch. An arch that has a rib composed of two lens-shaped trusses.

Linear arch. A linear arch is the equilibrium polygon for the system of loads applied to the physical arch. In an actual arch the resistance line is the linear arch for the actual loading.

Multi-centered arch. An arch having an outline composed of a series of circular arcs with different radii, giving an approximation to an ellipse. These arcs are symmetrically disposed about a vertical axis and occur in odd numbers.

* Am. Soc. C. E., "Soil Mechanics Nomenclature."

† From the American Institute of Steel Construction. For the most part, this section has been adapted, with minor changes and omissions of matter not relating to the structural-steel industry, from Waddell's "Bridge Engineering."

Oblique arch. An arch in which the axis is not perpendicular to the central plane of the structure.

Open spandrel arch. An arch in which the roadway is carried on spandrel columns or cross-walls.

Rise of an arch. The vertical distance from the springing line to the highest point of the intrados.

Segmental arch. A circular arch in which the intrados is less than a semicircle.

Skew arch. An oblique arch.

Striking of arch. Knocking out the wedges and lowering the centers, thus making the arch self-supporting.

Three-hinged arch. An arch hinged at the piers, at the abutments, and at the crown.

Thrust of arch. The horizontal reaction of an arch against its abutment; also the resulting pressure normal to the face of a radial section of an arch ring.

Two-hinged arch. An arch hinged only at the piers of abutments.

ARCH CENTER. A temporary structure for supporting an arch while in the process of construction.

ARCH RIB. A rigid curved beam either solid or built up of members like a truss.

ARCH RING. That portion between the extrados and intrados of an arch, sometimes called an "arch barrel."

AREA. The amount of surface included between certain closed boundary lines; any particular extent of surface, region, or tract.

Moment area. (Sometimes called "area moment.") The area enclosed by a moment curve.

Sectional area. The area enclosed by the periphery of a section of a piece or member.

AREA MOMENT. Moment area. *See* Area.

ASSAY. A test of the composition, purity, weight, etc., of metals or metallic substances such as ores or alloys.

AXIAL. Pertaining to or of the nature of an axis.

AXIS. A line about which a figure or a body is symmetrically arranged, or about which such a figure or body rotates; a principal line through the center of a figure or solid; a fixed line along which distances are measured or to which positions are referred.

Eccentric axis. An axis that does not pass through the center of gravity or the center of figure of the body considered; the axis about which an eccentric body revolves.

Longitudinal axis. An axis in the longitudinal direction of the figure or body considered, and generally passing through the center of gravity or the center of figure.

Neutral axis. The trace of that plane in a beam where there is no tension or compression and where no deformation takes place.

Polar axis. An axis at right angles to the plane of rotation.

B. AND O. A backing-out punch. *See* Punch.

BAR. Any piece of wood, metal, or solid material long in proportion to its cross section; also a barrier; an accumulation of silt, sand, gravel, or a combination thereof which is deposited in streams and forms an obstruction therein.

Anchor bar. An eye-bar extending from the shoe of a span or tower into the concrete or masonry of the supporting pier or abutment for the purpose of holding down the span that rests thereon in case it be subjected to uplift.

Arbitration test bar. A form of small test bar used for determining the quality of material going into a casting.

Boring bar. A machine tool consisting of a special bar with cutters attached, used in a lathe or boring machine.

Bucking bar. The bar on a ring dolly which bears against a rivet, so as to hold the head during driving.

Chisel bar. A heavy hand bar with a chisel edge on one end.

Claw bar. A hand bar with a bent, claw-shaped point for drawing spikes from railway ties or sleepers.

Connecting bar. A bar which joins two parts or two members.

Corrugated bar. A type of deformed bar used as reinforcement in concrete. The deformations consist of a series of ridges transverse to the axis of the bar, their function being to engage the salient portions of the aggregate.

Crowbar. A hand bar of steel with a slightly bent, wedge-shaped end, which is sometimes forked—used as a pry or lever.

Dolly bar. A riveter's tool or bar, used to hold the head of the rivet against the metal and act as an anvil while the other head is being made by a hammer.

Extension bar. A bar riveted to the end of a strut channel, and projecting beyond it, to permit the passage of a pin.

Holding-on bar. A lever which is used to hold one head of a rivet against the impact of the hammer while the other head is being formed with a snap.

Lacing bar. Any bar used in a system of lacing.

Merchant's bar. Wrought-iron bars in their finished form ready for sale.

Muck bar. The bar made by the first rolling of the bloom.

Natural bar. A bar of sand or gravel formed in a river bed by the usual physical process of precipitation.

Pinch bar. A form of crowbar with a short projection like a heel, or fulcrum, at the end—used to pry forward heavy objects.

Puddle bar. A muck bar.

Reinforcing bar. A bar or rod placed in concrete constructions to increase their resistance, especially to bending and shear.

Sand bar. A deposit of sand in a river.

Shackle bar. A bar used for pulling driftwood from a stream.

Shaker bar. A pick-up bar.

Tension bar. Any bar subjected to tension.

Z-bar. A rolled steel shape having a cross section resembling the letter Z and all angles right angles.

BARGE. A square-ended, flat-bottomed boat having capacity to carry bulky materials such as coal and rock; used for erecting spans by flotation.

BASCULE. A moving span that rotates in a vertical plane about an axis that may be either fixed or movable.

Rolling bascule. A bascule which retreats as it rises by having a cylindrical surface roll on a plane. In some types both surfaces are toothed.

Roller-bearing bascule. A type of bascule which has a fixed axis of rotation and which is supported on friction rollers to reduce the resistance to turning.

Trunnion bascule. A type of bascule which is supported by an axle or trunnions, about which it rotates without translation.

BASCULE LEAF. That portion of a bascule which actually revolves in a vertical plane.

BATTER. To strike with repeated blows; an incline from the vertical (said of a wall having a face receding as it rises); to incline a face or line in masonry or any other construction.

BATTLEDECK FLOOR. A steel floor system for bridges and buildings, devised and developed by the A.I.S.C., and consisting of steel plates and beams welded together so as to develop the whole as a T-beam section with continuity in all directions.

Bay. The portion of a trestle between two columns; the English term for a panel of a truss.

Beam. A member the principal function of which is to carry a transverse load.

Bethlehem beam. A special rolled beam having a thin web and wide flanges made in the Gray mill of four rolls—manufactured by the Bethlehem Steel Company.

Box beam. A hollow beam, generally rectangular in section, having its sides made of plates united by angle irons.

Built beam. A beam made up of structural shapes, such as plates and angles, riveted together.

Cantilever baem. A beam supported at one end only.

Carnegie beam. A special rolled beam having a thin web and wide flanges made in a special mill—manufactured by the Carnegie Steel Co.

Collar beam. A horizontal member stretching from one to another of two rafters which meet at the top, and which are above the main tie beam.

Continuous beam. A beam that rests on three or more supports.

Cross beam. A beam which runs transversely to the center line of a structure.

Deck beam. A rolled shape having a T cross section but with a slight enlargement at the lower end of the stem or web.

I-beam. A rolled structural shape having a cross section resembling the letter I.

Needle beam. A cross beam supporting a load, used in underpinning walls.

Rolled beam. A metal beam made by a rolling process.

Simple beam. A beam having its ends free and resting on two supports only.

T-beam. A reinforced-concrete beam or a rolled structural shape having a cross section resembling the letter T.

Tension beam. A beam subjected to tension as well as to cross-bending.

Transverse beam. Any beam of a bridge that passes from one truss to an adjacent truss.

Trussed beam. A beam braced by one or more vertical posts supported by inclined rods attached to the ends of the beam.

Bearing. That angular position of a line referred to a meridian; The support for a shaft, axle, or trunnion; the shoes for a span; the resistance to crushing as offered by a member; the pressure transferred from one member to another; the capacity of a pile to carry load; the support for a beam, pin, bolt, or rivet.

Allowable bearing. The maximum intensity of pressure on a support allowed by the specifications.

Center bearing. A term applied to swing spans to indicate that the dead-load support is near the axis of the pivot pier instead of near the periphery thereof.

Even bearing. A bearing in which the pressure is uniformly distributed.

Expansion bearing. A support at the end of a span where provision is made for the expansion and contraction of the structure.

Pin bearing. A type of end support for a girder or a truss in which a pin is used to transfer the load to the shoe.

Rim bearing. A term applied to swing spans to indicate that the dead load is supported by a circular girder near the periphery of the pivot pier instead of near its axis.

Rocker bearing. A bearing, or support, for solitary trestle bents or cantilever spans which permits of a slight rocking with the changing position of the live load and with variations of temperature.

Roller bearing. A shoe or plate resting on rollers which in turn rest on a base casting at the expansion end of the span.

Sliding bearing. A bearing constructed so that one part slides on another.

Thrust bearing. A support for a shaft adapted to take up the end thrust therefrom.

Bearing Point. The point of support for a load or a place where concentrated pressure is applied.

Beater. A bridgeman's maul.

Bedrock. The solid rock lying under loose detrital masses, such as sand or gravel.

Bell and Hopper. A charging device on top of a blast furnace.

Bent. *Column bent.* A bent composed of columns and bracing in contradistinction to "Pile bent."

Rocker bent. A bent, generally of steel, though sometimes of timber, hinged at either one or both ends so as to provide for the expansion and contraction of the span supported.

Solitary bent. A single bent of a trestle that is not attached to either adjacent bent except by the girders of the deck.

Trestle bent. In trestle construction, one of a series of bents carrying a deck.

Bent-Eye. An eye on the end of a bar, the plane of which makes an angle with the direction of the bar—formerly used in bridges, but now abandoned as unscientific.

Bessemer Process. A process for making steel by the decarburization of crude pig iron by means of a finely divided air current blown through the metal when in a molten state—named from its inventor, Sir Henry Bessemer.

Bevel. The slope on the end of a piece; an instrument for drawing angles—used by mechanics; to slope or sharpen an edge.

Beveled-Edge. An edge that is made thin by beveling.

Bid. To make a price on anything; a proposition, either verbal or written, for doing work.

Unbalanced bid. A bid in which some of the unit prices are abnormal, either too high or too low, or generally both.

Bill of Material. A list of the various portions of material for a construction, either proposed or completed, giving dimensions and weights or other quantitative measurements.

Billet. A small bloom; a short, chunky bar of iron or steel.

Bit. A tool for boring into wood or metal.

Blister. To raise filmy vesicles on a surface by heat; a small raised portion of a metal surface with a void beneath.

Bloom. A roughly prepared mass of iron or steel nearly square in section and comparatively short in proportion to its thickness.

Bloomated. Made into blooms.

Blooming Rolls. Rolls in which puddle balls of iron or steel are squeezed into blooms.

Blow. That portion of the time occupied by a certain stage of a metallurgical process in which the blast is used; to explode. In caisson work the term "blow" refers to the letting of air out of the working chamber so that the caisson may drop.

Blowhole. A defect in iron or steel caused by the escape of gas or air while solidifying.

Blueprinting. A method of photoprinting by using paper sensitized with ferroprussiate of potash.

Blue Shortness. A condition of brittleness in wrought iron caused by its having been worked at a blue heat.

Bolt. A cylindrical jet, as that of water; a metallic pin or rod having a head at one end and a thread on the other for screwing up a nut—used for holding members or parts of members together.

Anchor bolt. A round, steel bolt embedded in concrete or masonry to hold down machinery, castings, shoes, spans, engine beds, etc.

Assembling bolt. A threaded bolt for holding together temporarily the several parts of a structure during riveting.
Barb bolt. A bolt having jagged edges so as to prevent its being withdrawn from the object into which it is driven; also called a "rag bolt."
Bat bolt. A bolt barbed or jagged at the butt, or tang, to give it a firmer hold.
Blank bolt. A bolt having a fixed head, but no threads or nuts.
Clinch bolt. A bolt with one of its ends designed to be bent over to prevent withdrawal.
Construction bolt. A common steel bolt used temporarily during construction, such as a bolt to hold forms together.
Cotter bolt. Same as cotter pin.
Countersunk bolt. A bolt having its head beveled and flattened, so that when put into place the head will not project from the surface.
Drift bolt. A short rod or square bar to drive into holes bored in timber for attaching adjacent sticks to each other or to piles. The length generally varies from 1 to 2 ft. A drift bolt may or may not be provided with a head or with a sharpened end.
Expansion bolt. Any bolt similar to the "Brohard expansion bolt."
Eye bolt. A bolt having a loop or eye at one end in place of the customary flat head.
Fitting-up bolt. An ordinary bolt used to hold steel members together while they are being riveted.
Grip of a bolt. The length of a threaded bolt measured from inside of the head to inside of the nut when the nut is screwed on far enough to provide full thread.
Hook bolt. A bolt having one end in the form of a hook.
Key bolt. Same as cotter pin.
Lewis bolt. A wedge-shaped-ended bolt inserted like the shank of a lewis in a hole drilled in a stone and fastened therein by pouring melted lead into the unoccupied part of the hole; an eye bolt similarly inserted and used like a lewis for lifting heaving stones.
Lug bolt. A round bolt to which is welded a flat iron bar.
Machine bolt. A threaded bolt having a straight shank and a square or hexagonal head.
Skinned bolt. A bolt from which the threads have been stripped.
Tap bolt. A bolt that is screwed into the material that it holds instead of being screwed by a nut; also called a tap screw.
Through bolt. A bolt that passes from side to side of the members that it fastens.
Tie bolt. A round bolt with a square shank and lip for hooking ties to the flanges of stringers.
Toggle bolt. A bolt connecting the parts of a toggle.
Turned bolt. A machine bolt, ordinarily with hexagonal head, turned down so that when put in place it has a driving fit.
U-bolt. A rod bent in the shape of the letter U with threads and nuts on the ends.

BOOM. A long beam or spar projecting from near the foot of a derrick, and sustaining the load that is raised from its outer end. In England the term is used as a synonym for a chord of a truss.

Chicago boom. An erector's hoisting apparatus, consisting of a timber or steel boom, without a mast, having a gooseneck casting on the lower end working in a saucer block on a temporary sill, and held in position by blocks and tackle attached to other parts of the structure.
Derrick boom. The long member in a derrick that supports the load at its outer end.

BOOM BRACE. A tackle extending from the end of the boom to the top of the mast in a derrick; the trussing placed below or at the sides of the boom to strengthen it.
BOOM GUY. A line, cable, or adjustable rod fastened to the middle of a derrick boom and extending to the bull wheel to which it is attached so as to act as a brace.
BOOM IRON. A circular iron ring on the end of a mast of a derrick.
BOOM-OUT. The position of the boom at its greatest reach.
BOOM SEAT. The place in a derrick where the boom and the mast meet and rest on the sill.
BORING MACHINE. A machine used for boring holes.

Chord boring machine. A boring machine used in bridge shops for boring pinholes in chords.

BOTTOM LATERALS. *See* Lateral.
BRACE. Generally a strut supporting or fixing in position another member; a tie used for such a purpose; the permanent part of a small tool used for boring.

Batter brace. The inclined end post of a truss, sometimes called the "batter post."
Knee brace. *See* Knee.
Tension brace. A brace that resists tension.

BRACED. Strengthened or well interlaced and linked together by bracing.
BRACER. A brace.
BRACING. A system of braces, as in lateral systems.

Bottom lateral bracing. Lateral bracing in the plane of the bottom chords of a truss.
Cross bracing. X bracing.
Diagonal bracing. Bracing along diagonal lines.
Horizontal bracing. Bracing lying in a horizontal plane.
Horizontal sway bracing. Sway bracing in a horizontal plane.
Ladder bracing. Bracing consisting of struts only.
Lateral bracing. A system of tension or compression members, or both, forming the web of a horizontal truss connecting the homologous chords of the opposite trusses of a span.
Longitudinal bracing. Bracing extending lengthwise of the structure, or parallel to its center line.
Lower lateral bracing. Bottom lateral bracing.
Overhead bracing. The upper lateral or the vertical sway bracing in through bridges. The term is usually applied to the vertical sway bracing, if there be any; if not, to the upper lateral bracing.
Portal bracing. The combination of struts and ties in the plane of the end posts at a portal which helps to transfer the wind pressure from the upper lateral system to the pier or abutment.
Side bracing. The bracing on the sides of falsework, of a timber trestle, or of a pony-truss bridge.
Stringer bracing. Diagonal bracing in the plane of the upper flanges of the stringers.
Sway bracing. Bracing transverse to the planes of the trusses—used to resist wind pressure and to prevent undue vibration.
Top lateral bracing. Lateral bracing in the plane of the top chords.
Tower bracing. Bracing attached to the posts of towers.
Train-thrust bracing. Bracing in the plane of the bottom laterals that transfers the thrust of a braked train from the stringers to the trusses.
Transverse bracing. Bracing which is perpendicular (or but slightly inclined) to the center line of the structure.

Upper lateral bracing. Top lateral bracing.
Vertical bracing. Wind bracing lying in a vertical plane, such as sway bracing.
Wind bracing. Bracing that takes up the stresses induced by the wind.
X-bracing. Any system of bracing in which the diagonals intersect.

BRACING FRAME. A frame of steel or timber built in a manner to withstand distortion.

BRACKET. A knee, or knee brace, connecting a post or batter brace to an overhead strut.

Cantilever bracket. A bracket cantilevered out from another member.
Corner bracket. A steel bracket rigidly attached in a reentrant corner of a structure.

BRIDGE. A structure that spans a body of water, a valley, or a road and affords passage for pedestrians, or vehicles of all kinds, or any combination thereof.

Arch bridge. A curved structure that produces reactions inclined to the vertical.
Bascule bridge. A bridge having a span that opens by rotating in a vertical plane.
Cantilever bridge. A structure at least one portion of which acts as an anchorage for sustaining another portion that projects beyond the supporting pier.
Chain bridge. A suspension bridge in which chains are employed instead of the usual cables.
Combination bridge. A bridge constructed of timbers and steel or iron.
Combined bridge. A bridge that carries both railway and highway traffic.
Deck bridge. A bridge in which the passing loads are carried directly to the upper chords or to the upper portions of the posts.
Drawbridge. A bridge that may be drawn or turned to one side or lifted up, either bodily or in sections, so as to permit boats to pass under or through it.
Fixed bridge. One that does not move except for expansion and contraction.
Foot bridge. A bridge for foot passengers only.
Frame bridge. A bridge constructed of sticks of timber framed together.
Girder bridge. A bridge composed of plate or lattice girders.
Hanging bridge. A suspension bridge.
High bridge. A bridge over navigable water having ample clearance beneath it to permit the passage of all vessel traffic without moving a span or any portion of one.
Highway bridge. A bridge that carries highway traffic only.
Hinge lift bridge. A lift bridge that has its ends hinged together when down.
I-beam bridge. A small bridge consisting of a floor supported on I-beams.
Jackknife bridge. A bridge in which the lifting arms fold on themselves at midlength when in a raised position.
Lattice bridge. A bridge having riveted trusses with multiple intersection web systems.
Leaf bridge. A form of drawbridge in which the rising leaf, or leaves, swing vertically on hinges.
Leg bridge. A bridge resting on legs, formed by a downward extension of the end posts, instead of masonry abutments.
Lever draw bridge. A drawbridge operated by means of a lever.
Lift bridge. A type of movable bridge that travels in a vertical plane, sometimes called a hoist bridge.
Low bridge. A bridge over navigable water so low that some vessels cannot go beneath it without an opening passage being provided in the structure.
Motor bridge. A drawbridge operated by a motor; a bridge that carries motor cars.
Movable bridge. A bridge with a movable span.
Pile bridge. A bridge consisting of pile bents and timber caps, stringers, and bracing.
Pontoon bridge. A platform or roadway supported on pontoons or barges; a floating bridge.
Pull-back drawbridge. A movable span that retreats longitudinally to allow the passage of vessels.
Railway bridge. A bridge that carries railway traffic.
Revolving drawbridge. A drawbridge that turns in a horizontal plane.
Rolling drawbridge. A pull-back drawbridge.
Rolling lift bridge. A bascule bridge in which the moving arm rolls on a plane or upon friction rollers.
Skew bridge. A bridge in which the horizontal lines joining corresponding end pins of the opposite trusses are oblique to the planes of the said trusses.
Stiffened suspension bridge. A suspension bridge with stiffening trusses.
Stone bridge. A bridge built of stones laid in mortar.
Suspension bridge. A roadway suspended from chain or wire cables, usually hung between massive towers of masonry and securely attached to abutments; also called a wire bridge.
Swing bridge or swivel bridge. A span that rotates about a vertical axis so as to provide openings for the passage of vessels.
Through bridge. A bridge with overhead bracing and carrying its floor near the elevation of the bottom chords.
Trestle bridge. A bridge composed of bents or towers carrying the deck—may be of either timber or metal.
Truss bridge. A bridge made up of truss spans.
Tubular arch bridge. A bridge in which the primary supporting members are arched tubes.
Tubular bridge. A plate-girder structure covered with metal construction on top and bottom, forming a boxed space through which the traffic passes.
Vertical lift bridge. A bridge having a span that hoists vertically.

BRIDGE SEAT. That part of the top of a bridge pier or abutment that receives directly the pedestals or shoes of the superstructure.

BRIDGING. A piece of wood placed between and attached to two beams, or other pieces, in order to prevent them from approaching each other; also the spanning of any opening.

BRITTLE ZONE. In nickel steel testing, the stage between certain inferior and superior limits for percentage of nickel in the alloy where the metal is brittle, and both below and above which it is not.

BUCK. To resist; to afford resistance; to press against a rivet head with a dolly during driving.

BUCK BRACE. A cross frame.

BUCKER-UP. One who holds a dolly bar on the head of a rivet while it is being driven.

BUGGY. A small wagon used for transporting material such as rock; the carriage on which a traveling crane rests.

BULL PRESS. A gag press. *See* Press.

BULLDOG. Calcined tap cinder from puddling furnaces.

BULLDOZER. A machine in which angles are bent in small circular arcs by pressure between two supports.

BURNISH. To polish by rubbing—applied chiefly to metals.

BURR. A nut with a screw thread; the rough projecting edge of a drilled hole in steelwork.

Riveting burr. A washer upon which a rivet head is swaged down.

BUSTER. A machine for cutting off the heads of rivets; also the edged tool which does the cutting.

Bar buster. A rivet cutter on the end of a bar.

CABLE, *Suspender cable.* A hangar cable in a suspension bridge for supporting the floor system.

Suspension cable. One of the cables forming the support of the floor of a suspension bridge.

CALIPER. An instrument, consisting of two adjustable moving parts, used to measure the outside or inside diameter of a cylindrical body.

Inside caliper. A caliper for measuring any inside diameter.
Micrometer caliper. A caliper having a micrometer screw.
Outside caliper. A caliper for measuring the outside diameter of a cylinder or tube.
Vernier caliper. A steel caliper with a vernier attachment which reads to thousandths of an inch.

CALIPER COMPASS. A caliper made like a drawing compass or dividers with curved legs for measuring inside and outside diameter.
CALIPER GAGE. A tool or standard for measuring with great accuracy.
CALIPER RULE. An outside caliper formed by a rule having a graduated slide at one end.
CALIPER SQUARE. A rule carrying two cross heads, one of which is adjusted slightly by a nut, the other being movable along the rule.
CAMBER. The upward curvature of a member or truss above its nominal position.
CANCELATION. A system or arrangement of the web members in a truss.

Double cancelation. The arrangement of the web members of a truss having two complete systems of diagonals.
Multiple cancelation. The arrangement of the web members of a truss having more than two complete systems of diagonals.
Single cancelation. The arrangement of the web members of a truss having only one complete system of diagonals.
Triple cancelation. The arrangement of the web members of a truss having three separate systems of diagonals.

CANTILEVER. A bracket of stone, metal, or wood projecting from a supported beam or wall. *See also* Cantilever bridge, under Bridges.

Deck cantilever. A cantilever bridge in which the traffic is borne by a floor system supported by the top chords or the upper portion of the posts.
Through cantilever. A cantilever bridge in which the traffic passes between the trusses, in contradistinction to a deck cantilever where it passes above the top chords.

CANTILEVER ARM. The projecting arm in a cantilever bridge.
CAR, *Derrick car.* A railroad car upon which a derrick is mounted.

Erection car. A car specially fitted with a derrick and accessories, used for the erection of bridges.

CARNEGIE MILL SECTIONS. 8- and 9-in. wide flanged beams with beveled inside faces of flanges.

CASE HARDENING. Converting the outer surface of iron into steel by heating in contact with charcoal.
CAST. To make a casting of molten metal.
CASTING. The act or process of founding; that which has been cast by pouring molten metal into a mold.

Base casting. A steel or iron casting upon which the bridge shoe rests.
Centering casting. A casting used to bring a movable span to exact position when seated.
Chilled castings. Castings that are rapidly cooled during solidification.

CEMENTATION. The process of converting wrought iron into steel while heating it in contact with charcoal; the act of cementing; the act of uniting by adhesive substances.
CENTROID. The center of mass or center of gravity; the point of application of the resultant of a system of stresses or forces.
CHAIN, *Hog chain.* A chain cable or rod stretched over the straining posts in a hog-chain truss; the rod used for trussing a beam.

Hook and ring chain. A chain with a hook at one end and a ring at the other, called also a "sling chain."
Hook chain. A chain having a hook on one end or one at each end.
Ring chain. A chain having rings at the end.
Sling chain. A hook and ring chain.

CHAMFER. To bevel or sharpen to a blunt edge.
CHANNEL. A structural or rolled steel shape used in bridge building and in other steel constructions.

Built channel. A shape in the form of a channel fabricated from a plate and two angle irons.
Rolled channel. A channel which is rolled in one piece, in contradistinction to the built channel.

CHISEL. A hard tool consisting of a sharp-ended blade designed to cut under the impulse of a blow.

Cape chisel. A hand tool made from a short steel bar having one end flat and the other tapering to a blunt edge sharpened at an obtuse angle to prevent breaking—used in connection with a hand hammer for chipping cast iron. It differs from a cold chisel in having a narrower blade with more stock behind it.
Cold chisel. A hand tool made from a short steel bar having a flat top and a tapering wedge-shaped end a trifle wider than the shank—used for cutting metals while cold.
Hot chisel. A chisel used for cutting metals while hot.
Slogging chisel. A heavy chisel used for cutting off bolt heads.
Splitting chisel. A wedge-shaped chisel.

CHORD. That portion of a truss the main function of which is to resist bending on the span.

Bottom chord. The lower member of a truss, usually resisting tension.
Broken top chord. A top chord in which each successive segment deviates or deflects from the line of its contiguous segment, at the panel point.
Camel-back top chord. A top chord that is broken or deflects at two or, at most, three points.
Curved top chord. A top chord that approximates to the form of a curve. Strictly speaking, such a chord is "polygonal," as curving chords between panel points is not permissible.
Lower chord. Bottom chord.
Parabolic chord. A chord of a truss in which the panel points lie on the arc of a parabola.

Polygonal top chord. A top chord composed of panel length segments which form a polygon.

Top chord. The upper member of a truss, usually resisting compression.

Upper chord. Top chord.

Windward chord. The chord of a span on the windward side (the side from which the wind comes.)

CINDER. Slag, especially that produced from making pig iron in blast furnaces; ordinarily the residue of burnt coal, being the impurities thereof fused together to form lumps.

Puddle cinder. Cinder removed from the molten metal after the process of oxidizing the impurities has been completed.

CLAMP, FITTING-UP. An ordinary screw clamp, used for fitting up instead of bolts.

CLEAR HEADWAY. The vertical distance from the upper surface of a floor to the lowest part of the overhead bracing; the measure of height of the tallest vehicle that could pass through the bridge; also the vertical distance from the water surface or the ground to the lowest part of the superstructure.

CLEVIS. A connecting iron bent into the form of a horseshoe, stirrup, or letter U; a link in a chain shaped like the letter U; an adjusting piece for bridge members of varying length.

COEFFICIENT. A constant factor in an algebraic expression.

Differential coefficient. The measure of the rate of change in a function relative to its variable—used in the calculus.

Empirical coefficient. A coefficient established by experience or observation rather than by scientific deduction from fundamental principles.

COHESION. The force that holds together the individual particles of a body.

COLD CUT or COLD CUTTER. A cold chisel mounted on a handle like a hammer. It is used with the application of a maul.

COLD HAMMERING. The act or practice of hammering metal when cold.

COLD-PRESSED. Pressed when cold—applied generally to iron or steel.

COLD-ROLLED. Rolled when cold—applied generally to iron or steel.

COLD-SHORT. The condition of brittleness in steel when it is cold—caused by excessive phosphorus.

COLD STRAIGHTENING. The process of straightening metal when cold.

COLUMN. A pillar or strut; a long member which resists compression.

Bethlehem column. A wide H column rolled in a four-roll mill by the Bethlehem Steel Company, similar to the "Bethlehem beam."

Box column. A column made in the shape of a box, having sides of steel plates united by angles.

Carnegie column. A wide-flange H column rolled by the Carnegie Steel Company.

Channel column. A column made up of two channel irons laced or stayed.

Closed column. A column that is boxed in, shutting out water and air, generally making the interior inaccessible for painting.

Phoenix column. A fabricated column made up of rolled-steel segments riveted together forming a circular section with either four or six exterior projections through which the rivets pass.

Pin-end column. A column that is free to turn at either end about a pin.

Spandrel column. A column resting on the extrados of an arch and supporting the roadway above.

Z-bar column. A fabricated column composed of four Z-bars and one web plate riveted together.

COMBINATION PUNCH AND SHEARS. An apparatus that does both punching and shearing.

COMPONENT. A constituent part; one of the parts into which forces or stresses may be resolved or divided.

Horizontal component. A component of an oblique force taken in a horizontal line.

Longitudinal component. A component in a direction parallel to the plane of the trusses.

Transverse component. A component in a transverse direction, generally intended for a component perpendicular to the planes of the trusses.

COMPRESSION. The state of being compressed; shortening by pressure.

COMPRESSOR AIR. A machine by which air is compressed into a receiver that its expansion may be utilized as a source of power.

COMPUTATIONS. Calculations; the figuring of engineering structures.

CONCENTRATION. A system of loading in which several loads are collected and applied at a point or over a very small area.

Axle concentration. The load from one axle of a locomotive or vehicle concentrated on a structure, or twice a wheel load.

Double concentration. A term descriptive of the method of figuring stresses in bridges for a live load, consisting of a string of cars of uniform weight per lineal foot headed by an excess load equal to the difference between the total weight of an engine and tender and the product of the length of the two by the weight per lineal foot of the cars, and followed by another similar and equal excess load two panel lengths (about 50 ft.) back of the head of the train. This type of live load is no longer used, as it has been replaced by the "equivalent uniform live load."

Floor-beam concentration. The load transferred from one line of stringers to a floor beam.

Single concentration. Similar to double concentration except that the second excess load is omitted. It, too, is no longer used.

Wheel concentration. The amount of load carried and delivered by one wheel.

CONNECTING CHORD HEADS. Chord heads used to connect bottom chord or web channels to pins.

CONTRACTION. The act of drawing together or shrinking; diminishing the length area or volume of anything.

Coefficient of contraction. The ratio between the decrement of length, area of section, or volume, and the original length, area of section, or volume, For temperature change, it is the same as the coefficient of expansion. In hydraulics, it is the ratio between the area of the contracted section of a water jet issuing from an orifice and the area of the orifice.

Lateral contraction. A lateral shrinking or shortening.

CONTRAFLEXTURE. A reversal of bending in a column or beam.

CONVERTER. A Bessemer furnace. *See* Furnace.

COPE. To dress; to notch steel beams, channels, etc.

COPE CHISEL. A cape chisel. *See* Chisel.

COPING MACHINE. A machine for notching structural shapes.

CORROSION. The disintegration of a substance by the action of chemical agents.

Corrugated. Bent or drawn into parallel furrows or ridges; wrinkled; fluted.

Cotter. A beveled piece of wood or steel, used as a wedge for fastening; also a split steel key, used for the same purpose.

Counter. An adjustable diagonal in a truss, not subjected to stress except for certain partial applications of the live load.

Counterbore. The reboring of a cylindrical hold for a part of its length to a larger diameter than the original.

Counterbrace. A web diagonal which transmits a stress in the opposite direction (in relation to span length) to that carried by the main diagonal of the same panel.

Countersink. A drill or brace bit for countersinking; to form by drilling or turning a conical cavity in timber, metal, or other material, for the reception of the head of a bolt, rivet, or screw, so that the end thereof may lie flush with the surface of the said material.

Counterweight. A weight that counterbalances some other weight; to weight against.

Couple. Two equal and parallel forces acting in opposite directions and in different lines.

Moment of a couple. The tendency of a couple to produce rotation, measured by the product of one of the two equal forces by the perpendicular distance between them.

Stress couple. A pair of equal and opposite stresses lying in the same plane.

Crab. A short shaft or axle, mounted in a frame, having squared ends to receive hand cranks, used to wind up a rope and thereby raise a load.

Bracket crab. A hoisting apparatus fastened to a wall.

Derrick crab. A hoisting apparatus at the foot of a derrick; A special crab for a derrick.

Hoisting crab. Any crab used for hoisting.

Cradle. To incline suspending cables to the verticle.

Cradling. The placing of the cables in a suspension bridge so that they are closer at the sag than at the supporting towers.

Crane. A hoisting machine mounted so that it can move in a horizontal direction and thereby place the load at any point within its range.

Balance crane. A crane having two counterpoised arms.

Cantilever Crane. A crane in which the weight to be lifted is balanced by a heavy mass of material such as stone blocks or pig iron. It is generally capable of being rotated, the rear end being supported by a circular track.

Column crane. A crane built in the form of a latticed column with a curved overhand at the top; also called a "tower crane."

Derrick crane. A crane in which the post is supported by fixed stays in the rear, the jib being pivoted like the boom of a derrick.

Electric crane. A crane operated by electricity.

Gantry crane. A crane set upon a gantry.

Hydraulic crane. An apparatus for raising and lowering loads, acting on the principle of a hydraulic press.

Jib crane. A crane having a swinging boom.

Locomotive crane. A locomotive, or steam engine on wheels, with a crane attached—used in yard work.

Overhead crane. A crane that travels on elevated girders in a shop.

Rotary crane. A crane having a jib swinging in a complete circle.

Swinging crane. Any crane that has a boom that swings laterally.

Traveling crane. A crane mounted on wheels and capable of being moved from place to place.

Crimp. To offset an angle by bending so that it will fit over the flange of another angle, thus doing away with filler plates beneath.

Crimping Machine. A machine that crimps angles—used in bridge shops.

Cripple. To disable or to weaken; also to give or to give way.

Critical Speed. That speed of a train on a bridge which produces the maximum impact.

Crystalline. Consisting of crystals; relating or pertaining to crystals; having a definite structure referable to one of the crystallographic systems.

Curb. The edge of a sidewalk next to the main roadway; the wheel guard in a bridge.

Cutter. A steel tool for cutting metals; also the cutting edge on a cutting machine.

Bar cutter. A shearing machine that cuts metallic bars into lengths.

Cold cutter. See Cold cut.

Hot cutter. A tool for cutting metal that has been softened by heating.

Pinhole cutter. An apparatus for cutting pinholes in the chords or web members of a truss.

Pneumatic cutter. A cutter operated by compressed air.

Rivet cutter. A hand tool, similar to a cold cut but with edge sharpened on a more obtuse angle, used for cutting off the heads of driven rivets.

Cutting Edge. The edge of the tool that does the cutting. The edge of timber or steel angles placed on the bottom of the working chamber of a caisson.

Dead Man. A timber, log, or beam buried in the ground for anchorage.

Deck. The flooring of a bridge.

Double deck. A condition of a span having two decks, one over the other.

Decking, Flooring. Deck.

Deflection. A lateral motion; a motion at right angles to the length of the piece; also the amount of such motion expressed in some lineal unit as inches.

Dynamic deflection. The additional deflection caused by the live load being in motion.

Static deflection. Deflection due to a quiescent load.

Deformation. Change of form; a change of shape in a member or combination of members without any breach of the continuity of its parts.

Elastic deformation. A change of shape without impairment of the elastic properties of the material; a deformation with resulting stress inside the elastic limit.

Residual deformation. Deformation left in a member after the forces causing same have been removed; "permanent set."

Truss deformation. An alteration in the lengths and positions of the members composing a truss.

Depth. The downward distance from the surface or top. The term generally carries the idea of verticality but such is not always the case; for instance, the depth of any beam inclined to the horizontal is measured in a direction perpendicular to its length and, therefore, on a line inclined to the vertical.

Arch depth. The depth of the arch ring at any point at right angles to the axis.

Economic depth. That depth of truss or girder, which, when everything is considered, will give results that are satis-

factory from all standpoints and involve the least expenditure of money for properly combined first cost, operation, maintenance, and repairs.

Effective depth. The perpendicular distance between the gravity lines of a truss or girder.

Truss depth. The vertical distance between the center lines of the upper and lower chords.

DERRICK. An apparatus for lifting and moving heavy weights. It is similar to the crane, but differs from it in having the boom, which corresponds to the jib of the crane, pivoted at the lower end so that it may take different inclinations.

Bull-wheel derrick. A derrick with a bull wheel attached to the bottom of the mast in order to swing the derrick by ropes running to the hoisting engine.

Floating derrick. A movable derrick erected on a special boat, barge, or vessel.

Gin-type derrick. A framework with four stiff legs, used in borings, or for lifting pipes in trenches.

Guy derrick. A derrick in which the mast is guyed with cables to an anchorage.

Stiff-leg derrick. A derrick where stiff legs, usually of timber, take the place of guy lines for staying the mast. These stiff legs are attached to horizontal timbers which in turn are fastened to the bottom of the mast.

DESIGN. To proportion all the parts of a structure; a plan or plans, showing the various parts of a structure, their sizes, and relations.

DETAIL. One of the smaller parts into which any construction or design may be divided; to go into particulars; to draw the particular parts.

DETAILING. The actual work of planning and drawing the different parts and the connections of any structure; the smaller parts of any construction, speaking of them as a class.

DIAGONAL. A member running obliquely across the panel of a truss.

Lateral diagonal. A diagonal member in a lateral system.

Main diagonal. A web diagonal member joining the top and bottom chords of a truss, and taking its greatest stress when not less than one-half of the span is covered by the live load.

Sub diagonal. An intermediate web diagonal joining a chord with a main diagonal.

DIAGRAM. A sketch, outline, or skeleton drawing; a record made by curves plotted on cross-section paper.

Erection diagram. A skeleton drawing of a truss or span showing all pieces in their relative positions, properly lettered and numbered in order to facilitate the process of erection.

Force diagram. A diagram in which the amounts and directions of forces are represented by lines for the purpose of finding their resultant.

Frame diagram. A diagram of a frame in which the positions of the axes of the joints are shown by points, while the rigid connections are shown by lines between them.

Load diagram. A diagram showing the amounts and arrangement of loads on a structure; the diagram taken off an engine by an indicator.

Moment diagram. A curve showing the values of the bending moments in a beam or truss at various sections thereof.

Packing diagram. A drawing showing the arrangement or packing of the parts of a composite member or the disposition of several members meeting at a panel point. It refers generally to arranging truss members on pins in pin-connected structures.

Shear diagram. A diagram showing the variation of the shear along a beam or truss.

Skeleton diagram. A diagram which shows the general peripheral outline and the main members in a truss.

Stress diagram. A skeleton drawing of a truss, upon which are written the stresses in the different members. Also called "diagram of stresses."

DIAGRAM OF STRESSES. A stress diagram. *See* Diagram.

DIAPHRAGM. A thin plate or partition across a bridge member to stiffen it.

DIE. A steel former or device for shaping, impressing, or cutting out something.

DIES. Two flat plates of hardened steel having a semicircular groove cut in the edges making contact with each other. This groove has an internal thread, so that when the two pieces are brought together in a stock a female screw is formed. It is used for cutting threads on rods, bolts, etc.

DOG. A name for various mechanical devices, tools, etc., that usually grip something; the grappling iron which lifts the monkey, or hammer, of a pile driver; any part of a machine acting as a claw or clutch; a click or pallet that restrains the back action of a ratchet wheel.

Eye-bar dog. A special pair of tongs for lifting and moving eye bars.

Girder dogs. A special pair of dogs used for lifting and moving girders.

I-beam dog. A special pair of dogs for lifting and moving I-beams.

Ring dogs. A pair of dogs connected by a ring.

Sling dogs. A pair of dogs that have the outer ends of a cable sling fastened to the straight ends of the dogs.

Span dogs. Ring dogs.

DOG IRON. A short bar of iron forming a kind of cramp with its ends bent down at right angles and pointed so as to hold together the two pieces into which they are driven. Often the term "dog iron" is used for "dog hook."

DOLLY. A snap head; a tool with an indented head for holding the head of a rivet and absorbing impact while the other head is being driven.

Air dolly. A dolly operated by compressed air—used between two beams.

Bar dolly. A goose-neck or horse dolly that has an indentation for a rivet head at each end.

Bent club dolly. A club dolly having a bend in the hammer or anvil.

Bent dolly. A dolly with a bent offset at the center and only one end having the cup-shaped indentation for the rivet heads.

Club dolly. A dolly with a steel hammer head and an iron handle attached. The smaller end of the hammer head has a cuplike indentation for holding the rivet head. Usually a maul is held against the big end of the hammer head while rivets are being driven.

Combination dolly. A double-headed tool used for driving four different sizes of rivet—usually balanced on a chain.

Corrugated dolly. A straight dolly with one cupped end, the other being an oval knob.

Cup dolly. Any dolly that has a cupped end for receiving rivet heads.

Flat dolly. A hammer-headed dolly, flat on both faces for flattening rivet heads.

Goose-neck dolly. A dolly that has a quickly curved bend near one end, with both ends arranged for receiving rivet heads.

Heel dolly. A tee-headed dolly, having the far end rounded with a hole for a $\frac{7}{8}$-in. bolt located $1\frac{7}{8}$ in. away from the center of the tee head; also a dolly with a long shaft and a short right-angled bend at one end, the cup being in the short end.

Horse dolly. A goose-neck dolly.

Ring dolly. A dolly having a handle attached to two circular plates. These plates have a series of holes near the circumference on one side and a bucking bar on the other. A tap bolt goes through any of the holes and fastens to the handle, thus placing the bucking bar at any angle required.

Screw dolly. A straight dolly with a shaft that screws into the head—used between beams for bucking up.

Spring dolly. A dolly having a heavy hammer head attached to a long handle. Each end of the hammer has a cup to receive the heads of the rivets during driving.

Straight dolly. A cup-shaped dolly with a straight head and shank.

Double Intersection. Double cancelation. *See* Cancelation.

Double Latticing. Latticing.

Draw. The movable portion of a drawbridge.

Center bearing draw. A swing span supported on a central pivot.

Double rim bearing draw. A draw span supported on two rims or a double drum.

Double rotating cantilever draw. A movable structure composed of two adjacent swing spans, the inner ends of which are mechanically connected, and the outer ends of which engage with anchorages.

Revolving draw. A draw which turns in a horizontal plane.

Rim bearing draw. A swing span supported on a rim or drum.

Rotating draw. A revolving draw.

Wedge bearing draw. A swing span in which the live load, or a portion therof, is carried by wedges under the chords of the trusses.

Drawing. The making of a plan on paper, etc.; also the plan itself.

Detail drawing. A drawing on a large scale showing all small parts, dimensions, details, etc.

Erection drawing. An erection diagram. *See* Diagram.

General drawing. A drawing showing the elevation, plan, and cross section of the structure, also the borings for substructure and the main dimensions.

Perspective drawing. A drawing showing in perspective any structure.

Picture drawing. A general drawing attempting to show as a picture the actual way the structure would look.

Shop drawing. A drawing of a structure or machine showing all parts and dimensions so that the shop can actually build what is indicated on the drawing without other information.

Skeleton drawing. A skeleton diagram. *See* Diagram.

Working drawing. Any drawing showing all the parts and dimensions with other information pertinent to construction, so that whatever is shown can be built without other drawings or instructions.

Drawing Down. Reducing gradually the sectional area.

Drift. To enlarge a hole with a conical pin.

Drift Pin. A short, tapered rod for enlarging rivet holes.

Drill. To bore a hole in a material with a tool revolved by a suitable mechanism; the tool itself; the apparatus holding and turning it.

Center drill. A drill for making a central hole, as in a shaft.

Clamp drill. A drill having a clamp to hold it to the work.

Countersink drill. A tool combining a drill and a countersink in one piece.

Double drill. A drill with two cutters for making countersunk holes.

Fluted drill. A drill having two longitudinal grooves or flutes on opposing sides.

Forked drill. A slotted tool with a forked point used in a slot drilling machine.

Gang drill. A machine tool containing in one head a number of vertical drills, each having its separate belt and pulley operated from a common shaft

Hand drill. Any drill that is operated by hand. Usually one man operates both drill and hammer.

Machine drill. A drill mounted in a machine and run by power.

Pin drill. A drill for boring pinholes in truss members.

Pneumatic drill. Any drill operated by air.

Radial drill. A machine rock drill in which the drill tool is fastened to a radial arm.

Ratchet drill. Any drill operated by a ratchet mechanism.

Twist drill. A cylindrical drill having two parallel, spiral grooves on opposing sides and the point sharpened to an obtuse angle.

Drill Bit. The cutting tool used in a drilling machine; also called "drill."

Drilling Machine. A machine for boring holes in metals, rock, etc.

Drillings. The cuttings, or shavings, arising during the process of drilling; also the holes that are drilled in the ground.

Drill Plate. A breast plate for hand-drilling operations.

Drop of Beam. A term used in testing materials to indicate that a test piece has passed the yield point as shown by the sudden dropping of the weighing beam of the testing machine.

Eccentric. Out of center. A disk mounted out of center on a driving shaft and surrounded by a collar or a strap connected with a rod. Its purpose is to convert rotary motion into reciprocating rectilinear motion.

Elastic Limit. The unit stress at which the deformation begins to increase in a faster ratio than the applied loads.

Elasticity. That property which many bodies have of recovering their original form after the removal of the deforming cause.

Coefficient of elasticity or modulus of elasticity. The ratio of the direct stress per unit of area to the corresponding relative deformation, sometimes called "lineal modulus." The numerical value is equal to the stress per unit of area in tension that would be required to double the length of a piece, were the material of which it is composed perfectly elastic; also called "Young's modulus."

Shearing modulus of elasticity. The ratio of the unit shearing stress to the accompanying angular deformation. It generally equals two-fifths of the lineal modulus.

Volumetric modulus of elasticity. The ratio of the unit stress, applied on the three principal axes, to the relative change in volume. It generally equals two-thirds of the lineal modulus.

Element. That of which anything is in part compounded, which exists in it, and which is itself not decomposable into parts of different kinds.

Truss element. A component part of a truss.

Elevation. The projection of an object on a vertical plane, used in drafting.

Ellipse. A curve such that the sum of the distances from two fixed points, called the foci, to any point on the curve is a constant.

Elliptical Curve. An ellipse.

Empirical. Pertaining to or derived from experience or experiments.

Erecting Bill. A bill of material for a bridge, so arranged as to facilitate the finding and placing of members during erection.

Erection. The assembling of the members of a bridge in the field and making the necessary permanent connections.

Erection Drawing. An erection diagram. *See* Diagram.

Expansion. Enlargement; lengthening due to heat.

Expansion End. The movable end of a structure, trestle, span, truss, etc.

Extensometer. An apparatus for measuring minute degrees of expansion or contraction in metal bars under the influence of temperature or under stress.

Extrados. The convex curve of a masonry arch; the upper surface of the voussoirs when in position.

Eye. The hole in the end of a member to permit the passage of a pin.

Bolt eye. The eye in an eye bolt.

Loop eye. An eye on the end of a rod or square bar elongated in the form of a loop.

Slotted eye. An oval eye in the end of an eye bar in place of the usual round hole.

Eye Bar. A bar with an eye at either one end or each end.

Adjustable eye bar. An eye bar that can be lengthened or shortened after erection by means of a sleeve nut, turn buckle or clevis.

Trussed eye bar. An eye bar supported by trussing so as to resist compression or bending.

Eye-Bar Upsetter. A machine for enlarging the end of a plain bar sufficiently to permit the forming of an eye that will develop the full strength of the bar.

Fabrication. The act or process of framing and fitting rolled-steel shapes for structures; the putting together of parts of a structural-steel construction and riveting them.

Factor of Safety. Safety factor.

Fastening Angle. A connecting angle. *See* Angle.

Fiber. The longitudinal filament of a body.

Extreme fiber. The fiber most remote from the neutral axis.

Fibrous. Containing or consisting of fibers.

Fiery. The character or quality of steel as exhibited by its fracture when the grains are very coarse and bright.

Filler. A plate the sole function of which is to fill up space.

Pin filler. A ring placed on a pin between connecting members to keep them in position.

Fillet. The rounding of a sharp corner.

Fin. A thin projection on a surface of a casting caused by the imperfect contact of the two molding flasks each containing a part of the mold; a small, thin projection on the rolled surface of any metal, especially at the edges thereof.

Finish. The condition of a surface after the final work upon it has been performed.

Ground finish. A finish made on an object by grinding.

Planed finish. A finish produced by planing.

Rough finish. The finish which is left by the original forms, molds, etc.

Fish Belly. The form taken by some girders or trusses where the bottom flange or chord is convex downward; to swell downward.

Fitting-up. Assembling the different members of a structure and connecting them with bolts preparatory to riveting.

Fixed End. The anchored end; an end of a girder or strut so firmly connected as to prevent all motion in the vicinity of the end.

Fixed Point. Any point that is stationary or assumed to remain fixed throughout the entire discussion; the common center of gravity of a system of bodies.

Flange. One of the principal longitudinal members of a girder which resist tension or compression, also sometimes called the upper and lower chords of a beam; a projecting edge, rim, or rib on anything.

Flasks. The upper and lower parts of a box which contain the mold into which molten metal is poured.

Flat-head. A rivet or bolt head that has been flattened.

Flexure. Bending.

Common theory of flexure. The theory accounting for the stress intensity and distribution in a beam subjected to transverse loading on the assumptions that the flexure is slight, that the elastic limit is not exceeded in any part of the beam, that all plane normal sections remain plane after bending, and that the intensity of either tensile or compressive stress in any normal section acting parallel to the axis of the beam varies directly as the distance from the neutral axis.

Floor or Flooring. That part of a bridge or building which directly receives the travel or live load.

Ballasted floor. A bridge floor under a railway track upon which ballast is placed with ties embedded therein.

Battledeck floor. A steel floor system for bridges and buildings, devised and developed by the A. I. S. C., and consisting of steel plates and beams welded together so as to develop the whole as a T-beam section with continuity in all directions.

Buckle-plate floor. In bridgework a floor system that is composed of buckle plates for supporting pavement.

Corrugated-steel floor. A floor system composed of corrugated steel.

Solid-steel floor. A floor composed of steel beams and steel plates, such as flat, buckled, or trough plates.

Suspended floor. A floor attached to suspension cables or girders by hangers.

Trough-plate floor. A bridge floor system composed of trough plates.

Floor Beam. A transverse beam or girder placed at the panel points of a span to support the stringers that carry the floor.

End floor beam. The floor beam at the end of a span.

Intermediate floor beam. Any floor beam between the end floor beams.

Flux. To convert to a liquid state by means of heat; to melt; a substance that promotes the fusion of minerals or metals; the process of melting; fusion.

Footing. The spreading course at the base of a foundation.

Column footing. A footing, or spread base, under a column.

Force. That which moves or tends to move matter; the action between two bodies either causing or tending to cause change in their relative rest or motion.

Centrifugal force. The reaction of a body, due to its inertia, against that force which is causing it to deviate from a straight-line motion and to travel in a curved path; a fictitious force apparently balancing the central force.

Centripetal force. A force pulling a body toward the center of rotation.

Concurrent forces. Forces in which the lines of action intersect in a common point.

Impulsive force. A force that produces a finite change of motion in an indefinitely brief time.

Resultant force. See Resultant.

FORGE. To work wrought iron into shape by first softening by heat and then hammering into required form; the apparatus or furnace in which the iron is heated before being worked.

Rivet forge. A small forge used for heating rivets.

FORGE SHOP. A shop in which forgings are made.

FORGING. The process of welding metal or that of bringing it to shape when hot by hammering; also the article made by a forging process.

Drop forging. A forging produced by a drop press.

FORMER. A device for giving a particular shape to an article.

FORMING IRON. A blacksmith's swage block.

FORMULA. Any general equation; a rule or principle expressed in algebraic symbols.

Empirical formula. A formula pertaining to or derived from experience or experiments.

Rational formula. A formula derived from fundamental principles.

Straight-line formula. One of the several types of formulas used to express the resistance of columns. In this type the relation of the strength of the column to its length divided by its least radius of gyration can be represented by a straight line.

FOUNDATION. That portion of a structure, usually below the surface of the ground, which distributes the pressure upon its support; the supporting material itself.

Spread foundation. The spread portion below steel cylinders for piers; the spreading being done after the cylinders are sunk to place.

FOUNDRY. An establishment or plant where metals are cast.

Iron foundry. The place where iron castings are made.

FRACTURE. To break or split; a partial or total separation of parts of a continuous solid body under the action of force.

Angular fracture. A sharp-pointed or sharp-cornered fracture.

Columnar fracture. A cleavage into columns shown in the surfaces of the fracture.

Conchoidal fracture. A fracture showing shell-shaped depressions.

Crystalline fracture. A fracture leaving small crystals showing.

Cup fracture. A fracture in the shape of a cup.

Fibrous fracture. A fracture that shows the broken ends of fibers.

Granular fracture. A fracture showing grains or granules on its surface.

Irregular fracture. An extremely uneven fracture.

Silky fracture. A fracture showing a glossy surface.

Smooth fracture. A fracture either without any projections or having very few of them.

FUNCTION. A mathematical quantity that has a value depending upon the values of other quantities called the arguments, or independent variables, of the function.

Trigonometric functions. Certain functions of an angle or arc used in trigonometry, such as sine, secant, tangent, or their several reciprocals.

FUNICULAR POLYGON. An equilibrium polygon. *See* Polygon.

FURNACE. A structure in which a fire is maintained to heat materials or to melt metals or ores.

Acid open-hearth furnace. A furnace used in the manufacture of acid open-hearth steel.

Annealing furnace. A furnace in which the process of annealing is carried on.

Balling furnace. A furnace in which the fagots of metal are placed to be heated, preparatory to working.

Basic open-hearth furnace. A furnace used in the manufacture of basic open-hearth steel.

Bessemer furnace. A furnace mounted on trunnions so as to be tilted in either direction and having air-blast connections through the trunnions, used for converting pig iron into Bessemer steel by a process of decarburization.

Blast furnace. A furnace used in smelting iron ore.

Open-hearth furnace. In steel manufacture, a regenerative, reverberatory furnace in which the hearth is exposed to the action of the flame.

Puddling furnace. A reverberatory furnace in which cast iron is converted into wrought iron.

Regenerative furnace. An open-hearth furnace using producer gas as a fuel, but so arranged that the gas is conducted to the hearth area through a passageway filled with red-hot bricks stacked to form an open checkerwork. As the hot gas enters the furnace, it is mingled, in proper proportions, with air similarly heated so that complete combustion is produced. The escaping hot gases are conducted through a second passageway filled with bricks, which absorb much of the waste heat. The two passageways are used alternately to heat the producer gas as it is fed into the furnace.

Reverberatory furnace. A furnace having a vaulted ceiling which deflects the flames and heat toward the hearth where the ore is to be fused, the fuel being separated from the ore by a compartment.

Rotary furnace. A form of puddling furnace in which the hearth is made to rotate in a vertical or a horizontal plane in order to assist in removing the carbon.

GAG PROCESS. The process of bending structural shapes in a gag press.

GANG. A combination of several tools, machines, etc., operated by a single force, or so contrived as to be made to act as one; also a company or crew of men.

Bull gang. A crew of unskilled laborers for moving steel from the store yards to the bridge site.

Erection gang. A gang that does the work of erection.

Fitting-up gang. A gang that does the bolting up of the metal in a bridge shop.

Riveting gang. A gang that does riveting.

GANTRY. A frame or a scaffold that supports a crane or other structure.

GIB. A piece of metal in the shape of an elongated channel, used as a clamp.

GIN POLE. A mast, or vertical pole, guyed to the ground by cables —used in connection with blocks and tackle for raising weights.

GIRDER. A beam or compound structure acting as a beam carrying principally transverse loads that develop normal reactions at the supports.

Arched girder. A girder that is cut, bent, or built in the shape of an arch.

Bowstring girder. A girder consisting of a curved rib or beam, having a horizontal tension member arranged as a chord and connected to the rib by vertical tie rods.

Box girder. A type of girder having two webs giving a section resembling a box made up of plates and angles riveted together and forming flanges and webs.
Built girder. A girder made up of structural plates and angles.
Circular girder. A girder built in the shape of a circle.
Compound girder. A built girder.
Continuous girder. A girder with more than two supports.
Crane girder. A girder, either stationary or movable, used for hoisting.
Cross girder. Any girder passing across a bridge from one truss or main girder to another and, generally, perpendicular to the truss or girder planes.
Curb girder. A steel or reinforced-concrete girder holding up the sidewalk and forming the curb of a roadway.
Curved girder. Any girder in the shape of a curve.
Deck girder. One of the main girders of a deck bridge.
Deck-plate girder. One of the main plate girders in a deck bridge.
Expansion girder. Any girder one end of which is allowed to move.
Fascia girder. A longitudinal girder at the extreme edge of a structure so finished as to present a neat appearance.
Fish-bellied girder. A girder having the top flange horizontal and the bottom flange curved in the shape of a fish's belly.
Floor girder. Any girder that supports a portion of the floor and its load.
Framed girder. A girder constructed of timbers framed together.
Half-latticed girder or half-plate latticed girder. A lattice girder the ends of which have web plates while the central portion of the web is latticed.
Half-through girder. A loose expression for a girder of a half-through girder span.
Half-through latticed girder. A loose expression for a latticed girder of a half-through span.
Half-through plate girder. A loose expression for a plate girder of a half-through span.
I-beam girder. A girder composed of an I-beam.
Latticed girder. A riveted girder having the upper and lower flanges connected by latticing, or by diagonal bars or angles.
Longitudinal girder. The main girder in a structure running parallel to the entire line thereof.
Open web girder. A latticed girder.
Overhead girder. A girder that is overhead—usually moving on an overhead track as in a traveling crane.
Plate girder. A girder built of structural plates and angles.
Riveted girder. A girder built of plates and angles riveted together throughout.
Skid girder. A built-up plate girder with the web lying in the horizontal plane riveted to the inside of the web members of a truss to protect these members in case of derailment of trains.
Stiffening girder. A girder employed to give vertical stiffness, as in a suspension bridge.
T-beam girder. A girder built in the shape of the letter T.
Through girder. Incorrectly used for a "half-through girder." Strictly speaking, a through girder would mean a main girder of a tubular bridge.
Transverse girder. A cross girder.
Triangular girder. A latticed girder having a system of web members all inclined to the vertical.
Truss girder. A girder having a latticed web system forming with the flanges a truss in all essential features.
Trussed girder. A girder stiffened and strengthened by means of trussing.
Turntable girder. A fish-bellied girder used for a turntable.
Warren girder. A latticed triangular girder in which all the triangles are equilateral. Nowadays any triangular girder is spoken of as a Warren girder.

GIRT. Horizontal members from column to column to carry wall sheaths.
GOG PRESS. A gag press. *See* Press.
GOOSE-NECK. An iron or steel hook fitted into the inner end of a boom for temporary attachment to a clamp or an eye bolt; a curved pipe for discharging material from a caisson by means of compressed air; a piece of steel bent in S shape; a flexible coupling.
GRAPHICS. The method or process of solving problems by means of drawing lines.
GRAVITY. The force of attraction exerted by the earth on bodies near it; weight as distinguished from mass.

Axis of gravity. A line passing through the centers of gravity of successive elemental sections of a body.
Center of gravity. That point in a body about which the weights of all the various portions balance. It is found experimentally by balancing on a knife edge.
Line of gravity. The line along which the center of gravity would move, if the body were free to fall.
Plane of gravity. Any vertical plane passing through the center of gravity of a body.
Specific gravity. The ratio ofthe weight of a unit volume of a substance to the weight of a like volume of the standard substance, such as water.

GRILLAGE. A network of rolled or built beams put in a pier, to distribute the weight from the shoe, or at the bottom of a column to spread the weight over a greatly enlarged area.
GUN. A device for discharging missiles through a tube; also a hammer operated by air.

Air gun. A pneumatic riveting hammer.
Pneumatic riveting gun. A rivet hammer operated by compressed air.
Riveting gun. A riveting hammer.

GUSSET. An angular piece of iron or steel, or a steel plate fastened to angles, channels, or the members of a structure to give strength and stiffness to them, or to connect them to the construction.
GUY. A line for bracing the top of a pole, derrick, or any similar apparatus.
GUY LINE. A guy.
GYRATION. The act of revolving or gyrating.

Center of gyration. A point in a revolving body such that, if all the matter of the said body could be collected there, the body would continue to revolve with the same energy as when its parts were in their original places.
Radius of gyration. The radius of gyration of a body about a given axis is the distance from the axis of rotation to the center of gyration, and is equal to the square root of the mean of all the squares of the distances from the axis of rotation to all the points in the body.

H-PILE. Any steel H-section used as a bearing pile.
HAMMER. A hand tool consisting of a solid head of metal, wood, or stone set crosswise on a handle—used for beating, breaking, or driving; the part of a pile driver or of a steam hammer that strikes the blow; to beat or to drive.

Air hammer. A machine hammer driven by compressed air as an air riveting hammer.

Bust hammer. A hammer, used in riveting work, having a rivet buster on one end of the head and a hammer on the other end.

Cleveland hammer. One of the numerous makes of air riveting hammers.

Flogging hammer. A very large hammer used with a flogging chisel for chipping iron castings.

Holding-up hammer. A heavy engineer's hammer on a long handle, used in times past for bucking up rivets.

Peen hammer. A hammer having a peen on one or both faces.

Pneumatic hammer. A hammer operated by compressed air.

Power hammer. A hammer used for forging work.

Rivet hammer. A pneumatic or hand hammer for driving rivets. Also a light engineer's hammer for testing the tightness of rivets after driving.

Slogging hammer. A very heavy hammer head on a long handle used in past times for the hand driving of rivets.

Welding hammer. A hammer used in welding metals.

HEAD, *Button head.* The head of a bar, bolt, or rivet having the shape of a button.

Chord head. The enlarged head of a chord bar through which the pin passes.

Eye-bar head. The enlarged end of the eye-bar through which the pin passes.

Welded heads. Heads first worked into the desired shape and then welded on the bars.

HICKY BAR. A bar for bending slab reinforcement to shape.

HIP. The place at which the top chord meets the batter brace or inclined end post.

Inner hip. The intersection of the inner inclined end post with the top chord in the arm of a swing span.

Outer hip. The hip at the outer end of one of the arms of a swing span.

HODGKINSON'S FORMULA. An early column formula, devised by Eaton Hodgkinson, based upon Euler's formula; but modified to conform with experiments made at the time.

$$P = (\text{constant})\,\frac{b^4}{l^2}$$

where P = load; b = width of column; l = length of column.

HOIST. A machine for lifting weights or loads of various kinds; to elevate by means of block and tackle or by machinery of any kind.

Air hoist. A hoisting device, usually consisting of a cylinder, piston, and piston rod, operated by compressed air.

Assembling hoist. A hoist for lifting and assembling the component parts of trusses, spans, etc., in the shop or yard of a bridge plant.

Cable hoist. A hoist in which cables winding about a drum or drums are used to lift the load.

Chain hoist. A hoist in which chains are used for lifting loads.

Electrical hoist. A hoist operated by an electric motor.

Hydraulic hoist. A hoist operated by hydraulic power.

Pneumatic hoist. An air hoist.

Steam hoist. A hoist operated by steam.

HOISTING MACHINE. Any machine used for hoisting purposes.

HOLDER-UP. A dolly bar for bucking up rivets; also called "bucker-up."

HOOK. A piece of metal curved or bent so as to catch or grab something; to take hold with a hook.

Hand hook. A tool for twisting iron or steel bars.

Sister hook. A pair of hooks on the same axis facing each other and fitting closely together when in use.

HOOKE'S LAW. A law stating that the deformation of an elastic body is proportional to the force applied, or that the intensity of stress is proportional to the rate of strain.

$$\frac{dp}{dl} = E$$

where dp = the differential intensity of stress; dl = the differential of the rate of strain; E = a constant.

HOT SHORT. A condition of brittleness in iron or steel due to the presence of sulfur.

IMPACT. The act of striking; the forcible momentary contact of a moving body with another either moving or at rest.

Coefficient of impact. In structural engineering, the ratio of the effect of a dynamically applied load to that of the same load applied statically, less unity. In other words, it is the factor, nearly always less than unity, by which a static load effect must be multiplied in order to find the increment of the dynamic effect of applying the said load in a manner other than statically.

IMPACT-ALLOWANCE LOAD. A percentage allowance for impact applied to the equivalent uniform live load.

IMPACT-LOAD STRESS. Same as impact stress. *See* Stress.

INCH-POUND. A unit of energy or work; the work done in raising a pound vertically through an inch; a unit of moment equal to a force of 1 lb. acting with a lever-arm of 1 in.

INCLINED END POST. A batter brace. *See* Brace.

INERTIA. That property of matter by virtue of which it persists in a state of rest or of uniform motion in a straight line unless some force changes that state; the state or quality of being inert; indisposition to move or to act; inertness.

Center of inertia. That point in a body which is so situated that the force or combination of forces requisite for producing motion in the said body, or bringing it to rest or changing its motion in any way, is equivalent to a single force applied at the said point. This point coincides with the center of gravity of the body.

Moment of inertia. A function of some property of a body or figure—such as weight, mass, volume, area, length, or position—equal to the summation of the products of the elementary portions of such property, of said body or figure, by the squares of their distances from a given axis.

Polar moment of inertia. The moment of inertia about an axis perpendicular to the plane of rotation or to the plane of the area considered.

INFLECTION POINT. The point where reversal of curvature occurs; point of contraflexure.

INGOT. A large mass of metal cast in a mold.

Bled ingot. Ingots from the center of which molten steel has escaped, leaving a cavity.

INTERMEDIATE BENT. Any bent between the end bents.

INTERMEDIATE GIRDER. Any girder between the two outside girders.

INTERNAL FORCE. Stress.

INTERSECTION. A place of crossing; cancelation; a point common to two lines or a line and a surface.

Double intersection. Double cancelation. *See* Cancelation.

Multiple intersection. Multiple cancelation. *See* Cancelation.

Single intersection. Single cancelation. *See* Cancelation.

Triple intersection. Triple cancelation. *See* Cancelation.

IRON. A common but important and abundant metal having a specific gravity of about 8. The pure metal has a white, lustrous appearance, does not harden appreciably on quenching, and is strongly attracted by a magnet, although it cannot be made magnetic except when containing carbon, or while an electric current is passed around it. The term is often applied to a tool or utensil made of iron; also to various structural shapes.

Ball iron. An iron ore containing clay.
Bar iron. Iron made up in the shape of bars.
Blue-short iron. Wrought iron that has been injured and rendered brittle by being worked at a blue heat.
Bog iron. An iron extracted from ore occurring in marshy ground.
Channel iron. A rolled channel. *See* Channel.
Charcoal iron. Iron made in a furnace where charcoal is used as a fuel.
Chilled iron. Iron that is surface-hardened by sudden cooling at the time of casting.
Clamp iron. A clamp.
Cold-short iron. Iron that is weak and brittle when cold, owing to the presence of phosphorus.
Common iron. The poorest quality of commercial iron.
Corrugated iron. Sheet iron formed with ridges by passing it between fluted rollers.
Crystalline iron. An iron which when broken shows a crystalline fracture.
Double refined iron. Iron made by a process of cutting up bars of refined iron, placing the pieces in piles, then reheating and rerolling into shape.
Fibrous iron. An iron having a fibrous texture.
Forge iron. An inferior grade of iron used for puddling.
Foundry iron. An iron used in foundry work.
Galvanized iron. Iron coated with zinc.
Glazed iron. An iron containing a large amount of silicon.
Gray iron. A pig iron in which the carbon takes the form of graphite, giving the fracture a dark color.
Hot-short iron. Iron that is brittle above a temperature denoted by a medium orange color—owing to sulfur.
Ingot iron. Soft steel cast in ingots, sometimes with about 3% of copper added.
Junk iron. Scrap iron.
Malleable iron or malleable cast iron. Cast iron that has been rendered tough and malleable by long-continued high heating, while embedded in hematite, ferric oxide, etc., and then allowed to cool slowly.
Meteoric iron. Iron obtained from meteorites, generally containing about 10% of copper.
Mirror iron. A white, cast metal containing manganese—largely used in the manufacture of steel; also called spiegel, spiegel iron, and spiegeleisen.
Mottled iron. An iron in which part of the carbon appears as graphite, giving rise to alternate white and gray spots.
Muck iron. The lowest grade of wrought iron; iron ready for the rollers or squeezers.
Norway iron. A very pure wrought iron manufactured in Norway, used in making hooks for blocks, etc.
Pig iron. A term applied to cast iron when first run from the blast furnace into molds, giving small bars convenient for handling.
Red-short iron. Iron containing sulfur, copper, or arsenic, which will cause it to crack when bent at a red heat, but permitting of considerable tenacity when cold.
Refined iron. An iron made from muck bars cut up, mixed with scrap iron, reheated, and rolled.
Scrap iron. Old iron no longer suitable for its original purpose; waste iron; junk iron.
Sheet iron. Iron which has been rolled thin into sheets.
Swedish iron. A very pure wrought iron manufactured in Sweden—very expensive.
T or tee iron. Iron rolled into the shape of a bar having a cross section resembling the letter T.
Wire iron. A ductile iron from which wires are manufactured.
Wrought iron. In its perfect condition, wrought iron is simply pure iron, but, owing to impurities (to a certain degree) being present, it only approximates that condition.
Z-bar iron. Iron rolled in the shape of a bar having a cross section resembling the letter Z, but with the web at right angles to the planes of the flanges.

IRON FOUNDER. One who makes iron castings.

IRON MASTER. A manufacturer of iron.

IRON OXIDE. An intimate combination of oxygen and iron, such as rust.

IRON WORKER. A bridgeman or man who helps erect iron or steel.

IRONWORKS. The plant or place where iron structures are fabricated and assembled.

JACK. A lifting apparatus; a mechanical device, appliance, or part of a machine; to pry up or lift with a jack.

Ball-bearing jack. A jack having ball bearings to take up the thrust from the load and reduce the friction of operation.
Beveled-gear jack. A jack operated by power applied through bevel gears.
Differential jack. Any jack worked by differential gears.
Differential screw jack. A screw jack having a differential screw.
Hoisting jack. A lifting device in which a screw jack is employed.
Hydraulic jack. A device for lifting heavy weights or exerting great force by means of liquid pressure from a hand pump connected with a large-bore cylinder and a piston working therein.
Lifting jack. A screw jack worked by a worm wheel to which a handle is attached.
Rack-and-pinion jack. A jack using a rack and pinion to attain its lifting motion.
Rachet jack. Any jack worked with a rachet.
Screw jack. A large screw working in a nut set in a strong frame or forming a part thereof, which in turn serves as a base to carry the load.
Steamboat jack. A rachet jack similar to and operating on the same principle as a steamboat rachet, but with bearing shoes at the ends of the screws so that pressure may be exerted between two objects or parts of a structure.

JIG. Any tool or fixture used to guide cutting tools.

JINNI-WINK. Any short, light, stationary derrick used for raising small loads.

JOIST. One of the horizontal pieces usually laid in equi-distant rows to which flooring is fastened.

Bethlehem joist. A light-weight beam rolled by the Bethlehem Steel Company.
Binding joists. Joists used as girders to sustain common joists.
Steel joists. Joists made of steel.

JUMPER. A dolly; a monkey.

JUNIOR BEAMS. Light-weight steel beams rolled by the Jones & Laughlin Steel Corporation.

KILL. To hold molten steel in a ladle, furnace, or crucible until the ebullition of gas ceases and the metal becomes quiet.

KILLING. The act of holding steel to kill it.

KIP. A stress unit equal to 1,000 lb.

KNEE or KNEE BRACE. A short diagonal brace, used to connect a batter brace or a vertical post in a span to an overhead strut.

LACING. A system of bars not intersecting each other at the middle, used to connect two leaves of a strut in order to make them act as one member.

Angle lacing. A system of lacing in which angle irons are used in place of bars.

Double lacing. Erroneously used for "latticing."

Double riveted lacing. Lacing in which each bar is connected by two rivets at each end.

Single lacing. Lacing.

LADLE. A large vessel or pot for holding, transporting, and pouring molten metal.

LADLE BARROW. A special wheelbarrow for carrying a ladle of molten metal.

LAID-UP. A term used in riveting to denote that the dolly bar is tight against the head of the rivet preparatory to driving.

LATERAL. One of the pieces in a lateral system.

Bottom laterals or lower laterals. Laterals in the plane of the bottom chords.

Top laterals or upper laterals. Laterals in the plane of the upper chords.

LATERAL SYSTEM. A system of tension and compression members, forming the web of a horizontal truss, connecting the opposite chords of a span. Its purposes are to transmit wind pressure to the piers or abutments, to prevent undue vibration from passing trains or other loads, and to hold the chord members to place and line.

LATTICE. Latticing.

LATTICING. A system of bars crossing each other at midlength, used to connect the two leaves of a strut in order to make them act as one member. Generally the crossed bars are riveted together at their intersection.

Double latticing. Latticing.

Single latticing. Erroneously used for "lacing."

LAUNHARDT'S FORMULA. A formula pertaining to the fatigue of metals.

$$m = p_1 + \frac{n}{m}(f - p_1)$$

where m = maximum stress; p_1 = repetition limit when $n = 0$; n = minimum stress; f = ultimate static strength. This formula does not properly apply to any part of structural engineering.

LAYER-OUT. The person in a bridge shop who lays out the steelwork with templates.

LAYOUT. A plan or arrangement of the parts of a structure shown on a drawing.

Alternate or alternative layout. One of two or more different layouts, or schemes, for the same project.

General layout. A drawing showing an elevation, plan, and cross section for a structure, and any other notes—such as borings.

LEAF (OF A MEMBER). One of the vertical component parts of a built-up member, consisting generally of one or more web plates with top and bottom angles, or one rolled channel—usually two in number and sometimes three.

LEAST WORK. A method of determining stresses in the members of a redundant system.

Principle of least work. The stresses in the members of a redundant system have such values that the internal energy of all the stresses is a minimum.

LENGTH. Extension from end to end; distance measured along a line.

Effective length. That length of a member or structure used for the purpose of designing it; in a girder or truss, the distance between the points of support.

Gage length. The original length marked on a test bar for the determination of the elongation.

Panel length. The distance between two adjacent panel points in the same chord of a truss.

Unsupported length. The length of a compression member between the nearest points of lateral restraint.

LEVEL, *Dumpy level.* An engineer's level having a short telescope rigidly fixed to the supporting bar and vertical axis.

Engineer's level. A leveling instrument consisting of a telescope, having cross hairs, mounted on a supporting frame which can be brought to a level by means of screws, and which can be rotated about a vertical axis. A tripod serves to hold the instrument at a convenient height for the observer.

Precise level. A modification of the Y level with improvements and additions permitting of more accurate work.

LEVER ARM. The perpendicular distance from the center of moments to the line of action of a force; or, in the case of a couple, the distance between the lines of action of the two equal and parallel forces.

LINE. A unit of length, as one-tenth or one-twelfth of an inch; a row of anything; a limit, division, or boundary; a length without a breadth, or the trace of a moving point; a string, cord, or slender rope; a mark drawn by a pen or pencil.

Abutment line. The closing line of an equilibrium polygon.

Base line. A line adopted as a fundamental line in a survey from which other lines are run—used in triangulation work.

Center line. A line connecting the center points of anything.

Clearance line. A line on a diagram showing the minimum clearance allowed.

Closing line. The last line or side of a polygon, drawn or surveyed, which encloses the area.

Contour line. A line joining points having or representing equal elevations.

Datum line. A line of reference. This term is sometimes incorrectly used for "datum plane."

Fall line. A rope or steel cable used with pulley blocks in hoisting.

Guy line. A guy.

Influence line. A line that represents the variation of moment, shear, stress, deflection, or similar function at a particular point in the structure, due to a load of unity moving across it.

Load line. A rope or cable that carries the load; in graphic statics, the line of a force polygon on which the loads are laid off.

Neat line. The true face line of a building regardless of the projections of the stones; a line back of or inside of incidental projections.

Rupture line. The line along which rupture occurs or would occur if the piece were tested to destruction.

LINEAL. Relating to length only. (Often written "linear.")

LINEAL FOOT. A running foot.

LINEAR. Lineal.

Load. The weight carried by a beam, girder, truss, span, or structure of any sort, or any part of such structure, including its own weight.

Apex load. The load at a panel point of a truss.
Axle load. The load which comes on an axle of a wagon, car, or locomotive and is in turn transferred to the structure.
Breaking load. A load which when placed upon a structure or test piece would just be great enough to break it.
Centrifugal load. The horizontal load on a structure produced by the centrifugal reaction caused by the velocity and mass of a moving train as it passes around a curve.
Concentrated load. A load that is concentrated at a point or distributed over a very small area.
Crippling load. A load that, if put on a member or a structure, will disable or weaken it.
Dead load. The weight of all the parts of a bridge itself and anything that may remain upon it for any length of time, such as tracks, water mains, telephone and telegraph lines, snow, dirt, moisture, etc.
Eccentric load. A load which is applied to one side of the axis of resistance, and which, consequently, produces a bending moment on the piece considered.
Equivalent uniform live load. A load of the same weight for each unit of its length and practically equivalent in its effect to an assumed typical live load composed of varying wheel concentrations with various wheel spacings.
Excess load. An overload.
Fixed load. Any determined load.
Impact load. A load due to impact.
Impact-allowance load. A percentage allowance for impact from the live load.
Indirect wind load. A transferred wind load.
Limit load. The greatest load which a structure is permitted to carry as set forth in the specifications; a safety load.
Live load. A moving load on a structure.
Moving load. An advancing load on a structure.
Overload. A load which produces intensities of stress beyond the allowable unit stresses.
Panel load. An "apex load."
Permanent load. A dead load.
Proof load. The greatest load that can be applied to a member without producing permanent distortion.
Quiescent load. A load that is not in motion.
Rolling load. A moving load.
Safe load. Any load that does not produce stresses, in the members, having higher intensities than those allowed in the specifications.
Static load. A dead load.
Test load. A live load applied to any finished construction as an ocular proof of its safety.
Traction load. A load due to the kick back of the locomotive drivers running on the rails (equal to the drawbar pull), or the thrust from a braked train.
Transferred load. A load that has been carried over from another part of the structure to the member in question.
Transverse load. A load applied perpendicularly to the plane of the longitudinal axis of the member or the structure, such as a wind load.
Unbalanced load. A load without a counterpoise. It refers generally to loads from locomotive drivers.
Uniform load. A load that is uniformly distributed, or the same per lineal foot of span.
Wheel loads. Loads on the different wheels of a locomotive; also a system of wheel loadings.
Wind loads. A load on a structure due to the pressure of the wind.
Working load. A safe load established by the specifications.

Loading. A system of loads on a structure; the act of placing loads on vehicles.

Locus. In mathematics, a curve considered as generated by a moving point, or a surface considered as generated by a moving line; the partly indeterminate position of a point subject to an equation or to two equations in analytic geometry; a curve considered as generated by its moving tangent or by a moving curve of which it is the envelope; any system of points, lines, or planes defined by general conditions, and, in general, partly indeterminate.

Log. An abbreviation for logarithm. A bulky piece or stick of timber.

Logarithm. The exponent of the power to which a fixed number, called the base, must be raised in order to produce a given number.

Briggs' logarithm or common logarithm. A system of logarithms in which the base is 10.
Hyperbolic logarithm or Naperian logarithm or natural logarithm. A system of logarithms in which the base is 2.71828+.

Logarithmic Table. A table giving the logarithms of consecutive numbers and of trigonometric functions of angles.

Luff. To swing the boom of a derrick.

Lug. Any kind of a projection for carrying or supporting something.

Lute. A mixture of fire clay, used to seal cracks when heat is applied to furnaces.

Malleable. Capable of being shaped by a beating or rolling process.

Manganese. A metal resembling iron and having a strong affinity for it—used in the manufacture of all steels, the percentage thereof generally varying between one-half and unity.

Mass. The quantity of matter in a body. It is measured by the ratio of its weight to the acceleration due to gravity.

Center of mass. That point at which the mass of a body may be considered as concentrated without disturbing its equilibrium; the center of gravity or the center of inertia of a body.

Mast. An upright post of timber or steel, as the mast of a derrick.

Derrick mast. The upright member of a derrick, at the bottom of which the boom is attached and which is pivoted so as to allow the boom to swing either way.

Mast Sea. The casting at the foot of a mast on which it rests and turns.

Match Marking. A system of marking the parts or members of a structure so that they always may be connected in exactly the same order and manner.

Mechanics. The science of force and its effect upon matter. Though the word was originally used to mean the theory of machines, it has, by extension, come to denote the doctrine of force and the resulting motions or tendencies to motion of particles and systems of particles. As such, it is the fundamental one of all the physical sciences.

Melt. To fuse or liquefy by applying heat. "Melt" is employed by blast-furnace men to denote the metal fused, or the charge or heat, as it is sometimes called.

Dead melt. In the fusion of metals, a condition of being fully or completely melted, no gas being evolved.

Melt Number. The number given a heat or charge and carried by the product throughout the processes of rolling and fabrication.

Melting Point. The temperature at which a metal passes from the solid to the liquid state.

Member. A component part of a bridge or other structure, complete in itself.

Adjustable member. A member of a bridge, the length of which can be increased or diminished at will.

Main member or primary member. A principal part of a truss or floor system—generally restricted to trusses.

Redundant member. A superfluous member. Its use is avoided as much as possible in the most approved American bridge-engineering practice.

Secondary member. A subordinate part of a bridge, as a lateral. Generally it refers to the suspenders and subdiagonals of trusses.

Secondary truss member. A subsidiary member used to support a main member, or to transfer a load from a midpanel to a panel point or panel points.

Tension member. A member of a structure subjected to tension only.

Truss member. A truss element. *See* Element; Truss.

Webb members. The parts or sections forming the web of a truss.

Metal. As used in bridgework, this term means steel, unless specifically stated otherwise.

Fatigue of metals. The doctrine that states that repetitions or reversals of stress, if excessive, cause a deterioration of the metal. Strictly speaking, it does not apply at all to structural steel work.

Pin metal. The metal called for in the specifications, from which pins may be made.

Pot metal. A poor grade of cast iron.

Midspan. The center of a span.

Mill. A machine for rolling plates, shapes, rails, etc.; the plant where steel shapes, etc., are rolled; to remove metal by a circular tool having teeth as in a milling machine.

Boring mill. A large machine tool having a horizontal revolving table to which the object to be trimmed is fastened, and in which the cutting tool, except for feed adjustment, remains fixed in position while the object revolves—used for turning large castings and boring large holes.

Universal mill. A four-roll mill for rolling plates on both edges as well as on the faces.

Milling. The process of removing metal with a circular cutter in a milling machine.

Milling machine. A machine consisting of a rotating mandrel carrying a milling cutter, and a movable table, operated by a feed screw, to which is bolted the object to be milled.

Modulus. A number, coefficient, or quantity that measures a force, function, or effect.

Molecule. The smallest part into which any substance can be divided without destroying its chemical character.

Moment. The tendency of a force to produce rotation or of a stress or mass inertia to resist rotation. This tendency is measured by the product of the force into its lever arm.

Bending moment. The moment that produces or tends to produce bending in a beam or other member of a structure. It is measured by the algebraic sum of the products of all the forces by their respective lever arms.

Center of moments. The point about which a body tends to rotate; often a point arbitrarily chosen for convenience in determining the resultant moment of a system of forces.

Horizontal moment. A moment acting in a horizontal plane.

Negative moment. A relative term used to denote direction of rotation, usually taken counterclockwise.

Overturning moment. The moment of the external forces tending to overturn a structure.

Positive moment. A moment acting in the opposite direction to a negative moment, or acting clockwise.

Resisting moment. The moment that opposes distortion, displacement, or overturning; sometimes loosely used for moment of resistance.

Righting moment. The moment that tends to right a floating body after displacement.

Theorem of three moments. A theorem used in connection with continuous girders expressing the relation of the moment at any support to the moments at the preceding and following supports in terms of the loading and span lengths.

Twisting moment. Torque.

Moment Area. Area moment. *See* Area.

Moment-Area Method. The method for finding deflections in a framed structure by use of the moment-area curve.

Mold. A form or model pattern of a particular shape, used in fixing the shape of a plastic mass.

Ingot mold. A flask in which metal is cast into a large block or ingot.

Movable Bridge. More correctly speaking, a movable span.

Multiple Intersection. Multiple cancelation. *See* Cancelation.

Multiple System. A truss system having more than one system and usually more than two systems of cancelation.

Mushet Steel. A steel produced by the Mushet process of recarburization, which consists of adding spiegel or other form of manganese.

Mushy. The condition of a casting containing an excessive number of blow holes rendering it unsound.

Neck. That part of a test specimen, subjected to tension, which shows a reduction of area of cross section when the ultimate load is reached; to reduce suddenly the sectional area of a piece of metal; to nick.

Necking-Down. The act of reducing the cross section of a test specimen by stressing it beyond the yield point.

Nest (of rollers). A group of rollers, enclosed in a suitable frame or box, which support a bridge shoe.

Non-Concurrent. Applied to non-parallel forces not having a common point of intersection.

Nut. A short prism of metal having a central hole which is threaded to receive a bolt or a screw.

Check nut. An extra nut screwed on a bolt tight against the first nut to prevent the latter from working loose.

Driving nut. A special, flat-headed, hollow, round nut temporarily screwed on one end of a pin to receive the blows of the hammer or ram during the driving of the pin home.

Jam nut. A check nut.

Lock nut. A nut having some special provision to prevent turning.

Lomas nut. A nut having a recess on the bottom which permits it to be screwed down on the pin until the edges of the nut bear on the eye bars packed on the pin.

Pilot nut. A round nut, having one end tapering, which is screwed on a pin in order that it may be pushed through the eyes of the several eye bars and other members meeting at a panel point. After the pin is in place, the pilot

nut is removed, and a Lomas nut is screwed on in its place.

Pin nut. A special flat nut used on truss pins.

U-nut. A piece of iron or steel in the shape of a letter U, through which passes the threaded end of a rod, and which affords a bearing for the nut, with room to screw up the nut. Its use is not permissible in first-class bridge construction.

OFFSET. A short line run at right angles to a principal, or base, line; to move over from a base line to an auxiliary line called an offset line.

OIL HARDENING. The process of quenching red-hot steel in oil in order to harden it.

OLD MAN. An iron frame bent into the form of a U having hooks on the ends so that it can be hung to a bar, a rail, or the flange of a girder and used to form a bearing for a ratchet drill or reamer.

OPEN HEARTH. The hearth of a metallurgical furnace that is exposed to the direct action of the flame.

OPEN-HEARTH PROCESS. A process for the production of steel by the oxidation and removal of the impurities contained in a bath of metallic iron lying on the hearth of a regenerative furnace.

Acid open-hearth process. That process of producing steel from pig and scrap iron, in which the first step is to remove most of the silicon, manganese, and carbon from the molten mass. Just before tapping, spiegeleisen or an artificial ferromanganese is added to the charge in order to destroy the oxide slag and prevent red shortness. The furnace is lined with a silicious material.

Basic open-hearth process. That process of producing steel from pig and scrap iron, in which the first step is to remove the phosphorus and some of the sulfur as well as the silicon, manganese, and carbon. This is accomplished by charging the furnace with calcined lime, which unites with the excess phosphorus and holds it in the slag. The rest of the process is similar to the acid open-hearth process. To prevent the slag from attacking the lining, the furnace is covered with dolomitic limestone. Such furnaces are termed basic lined, and the process has become known as the basic open-hearth process because of this lining.

OPEN-WEBBED GIRDER. A latticed girder. *See* Girder.

ORDER BILL. A form of bill used in ordering material from the manufacturers.

ORDINATE. One of the coordinates in a system of rectangular coordinates defining the position of a point.

ORE BRIDGE. A gantry crane used for handling ore at a blast furnace.

OUTHAUL. A method used by erectors for assembling a member which is beyond the reach of the boom of the derrick. It consists in placing a pulley block ahead of the member beyond the derrick and doubling back the lead line to the hoisting engine.

OUTPUT. The production of a mill, plant, or company for a certain period.

OUTRIGGER. A beam or joist projecting from a structure, used to support a load at its end.

OVERBLOWN. A term applied to Bessemer steel that has been blown too long and is overoxidized and hence inclined to be wild.

OVERHEAT. To heat metal to a temperature near the melting point, causing it to become coarse grained and reducing the cohesion between the particles.

OVERMELT. To keep steel too long in a state of fusion.

OXIDE OF IRON. Iron-oxide.

PACKING PIECES. Short pieces, inserted between two others that are riveted or bolted together, to prevent their coming in contact with each other.

PANEL. That portion of a truss between adjacent panel points lying in the same chord.

Subdivided panel. A panel divided by a sub-diagonal or hanger.

Tower panel. The longitudinal space or bay in a trestle or viaduct occupied by the tower.

PANEL LOAD. An apex load. *See* Load.

PANEL POINT. The point at which the axis of a principal web member intersects the axis of a chord of a truss.

PARABOLIC FORMULA. Any formula having the form $y^2 = 2px$.

PARALLEL. A condition of being everywhere equidistant, not intersecting; applied to lines and planes.

PARALLELOGRAM OF FORCES. A method of determining the resultant of two forces, acting in the same plane, by constructing a parallelogram having sides equal and parallel respectively to the forces, whereupon the diagonal of the parallelogram will represent in magnitude and direction their resultant.

PATTERN. A model made of wood to duplicate the desired object. It is used to form the cavity in a mold into which the molten metal is afterward poured.

PEDESTAL. A footing for a tower post; a bridge shoe.

PEDESTAL BLOCK. A base casting. *See* Casting.

PHOSPHORUS. A chemical element having a strong affinity for oxygen, encountered as an impurity in iron ores. Its presence causes cold shortness in steel.

PICKLING. The treatment of iron or steel with dilute acids for the purpose of obtaining a clean surface by removing the scale (oxide).

PIG. The name given to cast iron that is drawn direct from the blast furnace and run, for convenience of later handling and transporting, into shapes known as pigs.

Basic pig. Pig iron used in making basic open-hearth steel in which the silicon content is limited to 1% and the sulfur to 0.5%.

Bessemer pig. Pig iron used in making Bessemer steel or acid open-hearth steel, in which the silicon content ranges from 1 to 2% of phosphorus not over 0.1%, and sulfur not over 0.5%.

Cinder pig. A pig iron made from smelting top cinder or bulldog with ores.

Forge Pig. An inferior grade of iron used for puddling and for some classes of foundry work.

Foundry pig. Pig iron used in foundry castings.

Malleable pig. Pig iron used for making malleable castings

PIG IRON. Pig.

PIG WASHING. A process of refining or removing much of the phosphorus and silicon, in which the molten pig iron is treated with fused oxides of iron (and sometimes mixed with oxides of manganese) is a reverberatory furnace.

PILLAR. A post or column.

PIN. A round bar of steel used for connecting members of a truss; also any round bar that fills a hole.

Chord pin. Any pin on, or very near, the center line of a chord.

Clevis pin. A pin used to connect a clevis with a plate.

Drift pin. A hand tool made of tempered steel with tapering ends and of a size that will permit its being pushed through a rivet hole—used to draw together the component parts of a member or adjacent members.

End pin. A truss pin at the end of a span connecting the truss to the shoe.

Mast pin. A vertical pin at the top of the mast of a derrick.

Shoe pin. The pin in a shoe that receives the load from a span or a column.

Truss pin. A pin used at the panel point of a truss to connect the several intersecting members.

PIN BOLT. A bridge pin having a head and a nut.

PIN-CONNECTED. A term applied to the method of joining the members of a truss by pins instead of using riveted connections.

PIN-END or PIN-ENDED. The condition of having a pin connection at the end of a member.

PINHOLE. A hole in a member through which the pin passes and connects with other members.

PINNY. An English term for a metal that contains enclosed particles of metal harder than the rest.

PIPE (IN METAL). A defect in an ingot due to the metal cooling from the outside inward, and the resulting contraction leaving a cavity near the center at the top.

PITCH. The slope of a roof; the distance from center to center of rivets; the degree of descent of a declivity.

PIVOT SPAN. A span in a bridge that revolves; called also "draw span" and "swing span."

PLAN. The general layout of a structure; the horizontal projection of an object or structure.

PLANER. A machine tool for planing metal.

Pit planer. A type of planer located in a pit so that large work may be placed thereon.

PLANISH. To polish metals by rubbing with a hard smooth tool.

PLANT. The fixtures, machinery, tools, apparatus, etc., used to carry on any manufacturing or erecting business.

PLATE. A flat piece of metal.

Anchor plate. A square or rectangular plate, or washer, at the bottom of an anchor bolt.

Base plate. The foundation plate of metal on which a heavy piece of machinery or the end of a bridge rests. This plate is usually set on masonry or concrete.

Batten plate. A stayed plate at the ends of a compression member; sometimes termed "tie plate" or "stay plate."

Beam-hanger plate. The plate beneath the ends of a floor beam for the beam-hanger nuts to press against.

Bearing plate. A plate that receives the bearing from a pin or a plate that bears on another plate.

Bed plate. A plate set in the top of the masonry to carry the load from the span.

Buckle plates. Flat, steel plates that are dished at regular intervals—used for floor plates.

Cap plate. The top plate on a steel column or post. It generally supports a load.

Checkered plate. A cast steel or iron plate having square, flat projections suggestive of a checkerboard. Its function is to give a foothold for horses.

Connecting plate. A plate used to connect two or more members of a truss.

Cover plate. A plate fastened on the flanges of a girder to give additional cross section thereto; a top or bottom plate of a chord member.

Diaphragm plate. A stiffening plate used in the interior of a column to give it additional strength and rigidity.

Filler plate. A plate used to fill open spaces under members or parts thereof.

Flange plate. A cover plate.

Gusset plate. A large connecting plate used at panel points to join the chord and the web members.

Hanger plate. A gusset plate connecting the hip-vertical to either the top or the bottom chord.

Hinged plate. A plate containing a pinhole for hinging the end of a member.

Jaw plate. The unsupported portion of the end of a compression member remaining after the outstanding legs of flange angles have been cut away, and its pin plates, which extend below the transverse diaphragm to allow the packing of other members on the same pin.

Name plate. A plate attached to a bridge showing the names of the designer, fabricator, and erector. Sometimes other names are added.

Pin plate. A plate riveted to the outside of the end of a member to give additional strength and greater bearing on the pin.

Reinforcing plate. An extra plate used to reinforce or strengthen a member.

Roller plate. A bed plate on which the rollers of the expansion end of a truss rest.

Sheared plate. A plate sheared from another larger plate; any plate the edges of which are sheared.

Shimming plate. A plate used as a shim for increasing the elevation of a bearing.

Shoe plate. The bottom plate of a shoe resting on the masonry.

Skimming plate. A cast-iron plate used to separate from the molten metal the small amount of slag that comes out of the furnace therewith.

Sole plate. A plate riveted to the bottom flange of a plate girder to bear on the masonry plate.

Splice plate. A plate used in splicing or joining two parts of a member.

Stay plate. A batten plate.

Tie plate. A batten plate.

Tongue plate. A plate riveted onto the end of a member and projecting beyond it, in order to make a connection with another member.

Trough plate. A rolled steel shape having a cross section similar to that of a trough with sloping sides—used for floor plates.

Universal mill plate. A plate rolled on a universal mill, giving thereto smooth, square edges.

Wall plate. A steel plate laid on a masonry or a concrete wall to carry the end of a beam and to distribute its load.

Web plate. The plate forming the web of a girder.

PLAY. A looseness in a joint or in parts of a machine or structure permitting some freedom of motion.

PLUGGED RIVET. A calked rivet. *See* Rivet.

PNEUMATIC RIVETER. An air riveter. *See* Riveter.

POCKET. A recess; a hole in rolled metal, as a cinder pocket.

Cinder pocket. A pocket made in rolled steel by rolling cinders into the metal. These may either remain or drop out of the rolled product, leaving holes or pockets.

Expansion pocket. A bracket or pocket carrying a sliding end of a girder.

POISSON'S RATIO. The ratio of the lateral deformation to the longitudinal deformation under longitudinal external forces.

POLAR. Relating to a pole or axis.

POLAR DISTANCE. Pole distance.

POLAR EQUATION. An equation connecting polar coordinates.

POLE DISTANCE. The perpendicular distance, in a force diagram, from the pole to the load line.

POLYGON. An enclosed figure having many sides and angles.

Equilibrium polygon. In graphic statics, the polygon drawn through a system of non-concurrent forces in order to determine the position of the resultant thereof. The sides

of the polygon are made parallel to the rays of an accompanying force polygon.

Force polygon. A polygon used in graphic statics to determine the magnitude and direction of the resultant of a system of forces. The sides of the polygon are made parallel to and equal in length to the forces. The closing line represents the magnitude and direction of the resultant.

Funicular polygon or string polygon. An equilibrium polygon.

PORTAL. The space between the batter braces at one end of a bridge; sometimes the term is applied to the portal bracing.

Skew portal. A portal on a skew span.

POST. A vertical, or nearly vertical, compression member.

Batter post. A batter brace. *See* Brace.

Beam-trussing posts. The short, perpendicular posts used in trussing beams.

Center post. An intermediate post on the longitudinal center line of a timber bent.

Collision post. An auxiliary post placed near the portal of a bridge to take up the shock of a derailed car or engine and prevent it from injuring the trusses.

End post. The post at the end of a truss.

Fixed post. A post having fixed ends.

Handrail post. A post supporting the handrail and its attachments; the vertical member of a handrailing.

Hinged post. A post having one or both ends connected by pins to other parts of the structure.

Inclined end post. An inclined compression member at the end of the truss; also called batter post and batter brace.

Intermediate post. A post between the two outside posts in a timber bent.

King post. The middle post standing at the apex of a king post truss; also called joggle post.

Queen post. The vertical post in a queen post truss.

Subpost. A secondary post used in a subdivided panel.

Tower post. A member of a tower which carries load directly to the pedestal; a tower column.

POUND-FOOT. A unit of moment, equal to that produced by a force of 1 lb. acting with a lever arm of 1 ft.

PRESS. A machine for exerting pressure upon an object.

Buckle-plate press. A machine for pressing sheet steel into buckle plates.

Bull press. A gag press.

Drill press. A machine tool for drilling holes, having one or more spindles carrying drill points that are moved forward by an automatic feed.

Gag press or gog press. A press consisting of two fixed horns and a ram, used for straightening structural shapes; also called bull press.

Hydraulic press. A press consisting of a water cylinder and movable plunger mounted in a frame. A small pump forces water into the cylinder and causes the plunger to move slowly, but with great pressure, against the object held in the frame.

Steel press. A machine used in the manufacture of steel for pressing or squeezing out the slag. The action thereof may be continuous or intermittent.

PRESSURE. The effect of pressing; the result of thrust.

Axis of pressure. A line passing through the centroids of pressure of different successive sections of a body.

Bearing pressure. The pressure on a bearing.

Center of pressure. The point at which the resultant of the pressures on a surface acts.

Wind pressure. The pressure on a surface produced by the wind blowing against it.

PROJECTION. The act, or result, of constructing rays or lines through every point of a figure, according to some system or law, and extending or projecting them to some plane upon which the figure or object is to be represented.

Isometric projection. A mode of geometrical drawing in which three planes are projected at equal angles upon a single plane, and all the measurements are upon the same scale —used at times to show machinery, buildings, etc.

Orthographic projection. That system of projection in which the rays are parallel. This is the system most largely used in engineering work.

PUDDLE. To convert cast iron into wrought iron by melting and stirring in a reverberatory furnace.

PUDDLE BALL. A lump of red-hot plastic iron taken from the puddling furnace for hammering or rolling.

PUDDLE BAR. A muck bar. *See* Bar.

PUDDLER. A workman who is employed in the process of converting pig iron into wrought iron; the attendant at a puddling furnace.

PUDDLER'S CANDLE. One of the jets of flame which spring from molten iron while the carbon is being removed in a puddling furnace.

PUDDLE TRAIN. A set of rolls for rolling puddle balls into muck bar.

PUDDLING. The act of making a puddle.

Dry Puddling. The old process of puddling iron in which very little, if any, of the phosphorus was removed, while the sand lining of the furnace combined with the iron which was oxidized, thus causing a heavy loss.

PUNCH. A machine for forcing or shearing holes in metal; to make a hole with a punch.

Backing-out punch or B. & O. punch. A hand tool used by erectors for backing out of the rivet hole that portion of the rivet remaining after cutting off the head.

Center punch. A marking punch that makes a small indentation in steel so as to locate the center for a rivet hole.

Gang punch. A machine that punches two or more holes at one operation.

Multiple punch. A gang punch.

Pilot punch. A machine punch in which the cutting tool is provided with a small central plug which fits into a hole in the material and acts as a guide for punching the larger hole.

Prick punch. A hand tool for marking metal; a center punch.

Ratchet punch. A punching machine that is operated by means of a ratchet wheel.

Single punch. A punching machine that makes one hole at a time.

Spacing punch. A punch with an arm extending horizontally and having on the end of this arm a small tool, called a spotter, which engages a template working on a frame, to which is attached the sheet to be punched. When the frame is moved so that the spotter enters the hole in the template, the punch acts.

Square punch. A machine for punching square holes.

Subpunch. To punch a hole smaller than the rivet to be used, so that the injured metal may be removed by reaming out to size.

Template punch. A spacing punch.

PUNCHING MACHINE. A punch.

PUNISH. To subject material to very severe or abusive treatment.

PURLIN. A member laid horizontally upon the principal rafters of a roof to support the covering.

PUSHER. A subforeman, in charge of one gang, who sees that the men do the work assigned to them as rapidly as possible.

QUIESCENT LOAD. A stationary load.

QUIRK. An acute angle or recess; a deep indentation.

RABBLING. Puddling.

RACKING. Shaking so that the connecting rivets are loosened and the structure thus permanently injured.

RAFTER. One of the members in a roof to which the roofing is fastened.

Jack rafter. One of the short rafters used in a hip roof.

RAIL, *Guide-rail.* An additional rail placed inside of and close to one of the ordinary rails to prevent trains from leaving the track on curves.

Handrail. A railing of concrete, stone, wood, or metal placed on top of posts or balusters to form an open-work construction—used on the sides of bridges to prevent persons and animals from falling off.

Pipe rail. A handrail, used on bridges, composed of wrought-iron pipe and fittings.

Safety rail. A guard rail.

RAKE. The inclination to the vertical which a member of a bridge takes.

RAMP. An inclined plane connecting two levels.

RAYS. The lines in a force diagram drawn from a selected pole to the ends of the several lines representing the forces in the load line.

REACTION. A passive force set up in opposition to an initial, active force, *e.g.*, the upward pressure on the bottom of a beam resting on a support, equal in amount to the downward pressure from the beam.

End reaction. The reaction set up at the end of a beam, girder, or truss by the loads thereon plus its own weight.

Negative reaction. A reaction caused by an uplift, and therefore acting in an opposite direction to a reaction caused by a direct load.

Positive reaction. A reaction caused by and opposed to a direct load.

Upward reaction. A reaction having an upward direction. This is generally the same as "positive reaction."

REAM. To enlarge a hole by means of a cutting tool having fluted cutters on the side.

REAMER. A tool having fluted sides with cutting edges used for enlarging holes; also the machine that rotates the cutting tool.

Air reamer. A reaming machine operated by compressed air.

Close-quartered reamer. A pneumatic reamer having a cutting tool with a short shank, for working in restricted spaces.

Common reamer. A tapered bit with fluted sides and having sharp cutting edges.

Countersinking reamer. A bit with a conical-shaped cutting head—used for countersinking holes.

Expanding reamer. A reamer having a device that can be expanded after its insertion in a hole so as to make an under cut.

Flat reamer. A tapered flat bit with chisel cutting edges.

Fluted reamer. A common reamer.

Hand reamer. A reaming machine operated by hand.

Ratchet reamer. A reamer rotated by a ratchet mechanism.

REAMING. Cutting with a reamer in order to enlarge rivet holes in steel.

REAMING IRON. A round, tapering tool with cutting edges for enlarging rivet holes; a reamer; an iron tool used to open the seams between planks, so that they may be more readily calked.

REAMING BIT. The cutting tool used with a reaming machine.

RECARBURIZATION. The adding of carbon in some form to metal partially decarburized in some steelmaking process in order to obtain the proper percentage of carbon in the finished product.

RED SHORT. A condition of brittleness in iron at red heat.

REDUCED LOAD CONTOUR. A graphical means of representing the combination of different loads coming upon a structure, so as to give the value of the combination at any point by the ordinate to a curve known as the "reduced load contour."

REDUCTION. The production of metal from ore.

REFUGE BAYS. Platforms built on the side of a trestle or bridge so that men and hand cars can be got out of the way of approaching trains.

REHEATING. Heating a second time—used in tempering steel.

REPHOSPHORIZATION. Adding phosphorus when too much has been removed during the manufacture of steel.

RESILIENCE. The amount of energy which can be stored in an elastic body, up to a given stress per square inch, and which can be given out again by the body as useful work.

Coefficient of resilience. The amount of energy absorbed per unit volume of the body. This is affected by the class of deformation whether axial, bending, or torsional; hence there are three kinds of coefficients of resilience.

RESISTANCE. The passive opposition or reaction to any action.

Axis of resistance. A line connecting the centers of resistance of successive sections of a member.

Center of resistance. The point of application of the resultant of all the resisting forces.

Electrical resistance. That property of a body or conductor by virtue of which the passage of an electric current is opposed.

Line of resistance. The axis of resistance.

Moment of resistance. The sum of the moments of all the resisting forces at a section of a member.

Tensile resistance. The ability of a member to resist elongation.

Ultimate resistance. The greatest resistance that a body can develop.

Uniform resistance. Resistance that is uniform over the whole cross section.

RESISTANCE OF MATERIALS. That property of bodies, due to molecular forces, by virtue of which they oppose the displacement of their molecules; the resistance which a body offers to distortion, or to deformation by an external force; also called the strength of materials. This term is also applied to the branch of mechanics that deals with the phenomena of resistance.

RESOLUTION. The resolving of forces into their components.

RESOLVE. To analyze a force into its several component forces according to the principle of the parallelogram of forces.

RESTITUTION. The ability of an elastic body to recover from deformation due to impact.

Coefficient of restitution. The ratio of the total momentum after impact, to the total momentum before impact, in a system of colliding bodies.

RESULTANT OR RESULTANT FORCE. A directed force having an effect equivalent to that of two or more other directed forces.

RIB, *Stiffening rib.* The webs in a shoe, casting, or baseplate.

Rib Shortening. The contraction in an arch rib due to the axial stress set up by the loading or by a rise in temperature.

Rigid Body. A body possessing rigidity or stiffness.

Rigidity. The quality of being rigid or resistant to distortion.

Relative rigidity. A comparison of the rigidities of two bodies.

Ring Chain. A chain having rings at the ends and often one or more intermediate ones.

Rivet. A short iron or soft-steel rod with a head at one end. It is heated and put into a proper hole, and the other end is hammered down until a suitable head is formed.

Calked rivet. A rivet that has not been properly driven so as to fit tightly in the hole, but to which a seeming tightness has been given by turning the edge of the head under with a cold cut or similar tool.

Countersunk rivet. A rivet used in countersunk holes in which the point, while hot, is hammered down to fill the countersinking.

Field rivet. A rivet driven in the field during the erection of a steel structure.

Flat head rivet. A rivet that has the point hammered flat instead of round.

Grip of rivet. The thickness of the plates or parts through which the rivet passes.

Pitch of rivets. The distance between the centers of adjacent rivets in the same line.

Plugged rivet. A calked rivet.

Shop rivet. A rivet driven in the shop.

Snap-head rivet. A rivet having its head formed by a snap.

Stitch rivets. Rivets placed at intervals between two component parts to hold them together and give lateral stiffness.

Riveter. One who drives rivets; a riveting machine.

Air riveter. A riveting machine which is operated by compressed air.

Alligator riveter. A jaw riveter worked by the action of a cam, used in shopwork.

Bull riveter. A form of stationary, yoke riveter set in a vertical position and having a large cylinder at the end of one of the arms. The piston moves with a short stroke in a horizontal direction and the former on the end of the piston rod upsets the shank and forms the head in one movement of the piston.

Horseshoe riveter. A form of yoke riveter hung from a traveling crane, so as to be readily moved about the shop to reach different parts of a job.

Hydraulic riveter. A riveting machine operated by water under pressure.

Pneumatic riveter. An air riveter.

Steam riveter. A shop riveter driven by steam.

Toggle riveter. A riveting machine using a toggle mechanism to give the pressure required to upset the stem and form the rivet head.

Yoke riveter. A machine riveter in which the hammer is attached to one end of an elongated, narrow yoke and to the anvil at the other, the yoke permitting the reaching of rivets remote from the edge of the plates to be riveted.

Rivet Hole. The hole through which a rivet is driven or to be driven.

Riveting. The fastening of plates or parts together by means of rivets.

Butt riveting. The making of a butt joint by using cross plates and rivets.

Chain riveting. A term applied to riveting where the rivets in the second or succeeding rows are placed directly back of those in the first or preceding rows.

Cross riveting. Staggered riveting.

Double riveting. A term applied to riveted joints in which a double row of staggered rivets is used for a lap joint and two double rows for a butt joint—one double row on each side of the joint.

Hand riveting. Driving rivets by hand.

Lap riveting. The making of a lap joint by using rivets to fasten the overlapping ends of the plates.

Single riveting. A term applied to lap joints in which one row of rivets only is used to fasten the plates.

Staggered riveting or zigzag riveting. Rivets set in zigzag order, or so spaced that the rivets in one row are opposite the centers of the spaces of the adjoining rows.

Rivet Set. A rivet snap. *See* Snap.

Rivet Stem. The shank or that portion of the rivet under the head.

Rivet Tongs. Tongs used by field riveters for throwing and placing hot rivets.

Rolling Load. A moving load. *See* Load.

Rolling Mill. A mill.

Rolls. A machine consisting of several rollers, mounted in a frame, having intermeshing gears producing a positive motion —used in shaping steel ingots into bars, beams, angles, etc.

Puddle rolls. A machine having heavy, grooved rollers, between which lumps of plastic iron, taken direct from the puddling furnace and hammered into rough bars, are first rolled.

Straightening rolls. Rolls in a steel mill used for rerolling bars, beams, channels, etc., which had been bent during manufacture.

Rotation. Turning around on an axis or center; rotary motion.

Axis of rotation. A line passing through the center of rotation and perpendicular to the plane of rotation.

Center of rotation. The point of a rotating body that remains at rest while all the other points revolve around it.

Negative rotation. Rotation in a direction opposite to that of the hands of a clock.

Positive rotation. Rotation in the same direction as that of the hands of a clock.

Rounds. Round bars in the bracing system of a highway bridge; the rungs of a ladder.

Rupture. To break apart; the act of breaking apart.

Angle of rupture. The angle made with the transverse axis by the break in a test piece.

Joint of rupture. That joint in a voussoir arch for which the tendency to open at the extrados is the greatest.

Modulus of rupture. The unit stress at which a piece fails.

Plane of rupture. The plane along which failure occurs.

Rust. An oxidization of a metal.

Iron rust. The oxide of iron.

Safety Factor. The ratio of ultimate load to the greatest allowable working load. This term is losing favor with engineers, as it has been abused. There is no such thing as a factor of safety for a well-proportioned bridge, for each member should have an intensity of working stress proportional to the character and amount of work which it has to perform. This is best accomplished by adding to the live-load stress a certain varying proportion thereof to allow for the effect of impact.

SCALE, *Hammer scale.* A scale of oxide which forms on bars when heated.

Iron scale. A loose coating of oxide that forms on heated iron during the process of forging.

SCRAP. Discarded material; junk.
SCRAP PILE. A heap or a pile of junk.
SCREW JACK. A jack screw. *See* Jack.
SCRIBE. To trim off the edge of a board, etc., so as to make it fit closely at all points to a certain line; to mark with a scriber.
SCRIBER. A sharp-pointed tool for marking metal.
SCURF. To flake off, or the material that flakes off; dross.
SEAM. A crack in a badly rolled steel section.
SECTION, *Cross section.* A section made by a secant plane perpendicular to the axis of the member, structure, or any construction.

Dangerous section. That section or position where failure of a member is most likely to occur.
Fracture section. The section at which failure occurs.
Cross section. Total section.
Horizontal section. A section made by a horizontal secant plane.
Lateral section. A section made by a secant plane parallel to the side of an object.
Longitudinal section. A section made by the secant plane passing parallel to the long axis of the member.
Meridian section. A section of a sphere made by a plane passing through and containing a diameter.
Net section. Used improperly for the net area of a section; *i.e.*, the available area of a member after the rivet-hole areas are deducted.
Star section. A section of a member having the shape of a four-pointed star.
Transverse section. A cross section.
Uniform section. The condition of having the same section for all parallel positions of the secant plane.

SECTION MODULUS. The moment of inertia of the area of a section of a member divided by the distance from the center of gravity to the outmost fiber.
SECTION REQUIRED. The section area of a member required properly to resist the total force acting on the said member.

Self-Hardening steel. Mushet steel. *See* Steel.

SEMI-CANTILEVERING. A method of erecting a span without falsework, by cantilevering from an adjacent span, or adjacent spans, and afterward removing these so as to leave the structure as a simple span.
SET. The permanent change or deformation which a material subjected to stress undergoes when its elastic limit is exceeded; a tool for shaping rivet heads.

Button set. A rivet set or snap, giving a button shape to the rivet head.
Rivet set. A tool for shaping the heads of rivets; often called a snap.

SHAPE. Any rolled beam or bar used in a structure.
SHAPE STEEL. A shape.
SHAPER. A machine tool for planing or finishing metal.
SHEAR. To slide one part of a body upon an adjacent part; the stress set up in opposition to a shearing action.

Counter shear. A shear in opposition to another shear.
Double shear. A sliding on two different but parallel planes.
End shear. The shear at the end of a beam or girder.
Longitudinal shear. A shear parallel to the longitudinal axis of a member.
Negative shear. A relative term usually applied to a shear producing a downward motion.
Positive shear. A relative term usually applied to a shear producing an upward motion.
Residual shear. A permanent shear deformation.
Single shear. A sliding, or a tendency to slide, on one plane.
Transverse shear. A shearing action parallel to the transverse axis of a body.

SHEARED EDGE. An edge of a plate that has been cut in a shearing machine.
SHEARING MACHINE. A machine for shearing metal, consisting of a movable jar-cutter operating against a fixed cutting edge.
SHEARS. A shearing machine.

Angle shears. A shearing machine especially adapted for cutting angles.

SHEET PILE. A specially rolled steel pile, designed so that each pile interlocks with those adjacent to it.
SHELF ANGLE. A seat angle. *See* Angle.
SHOP. The place where structural steel is fabricated.

Machine shop. A shop for metal turning, planing, and drilling.
Pattern shop. A woodworking shop in which patterns are made.

SHUT. A seam or opening in metal formed during manufacture.

Cold shut. The freezing over of the top surface of an ingot before the mold has been filled, due to an interruption of the stream of molten metal.

SIEMEN'S PROCESS. A process for making steel by using a regenerative gas furnace which utilizes the heat of the escaping gases in reheating firebricks placed in the passageways for air and gas leading to the furnace. Two sets of passageways are required, being used alternately. While one is conveying the gas and air to the metal, the other is being reheated by the escaping gas from the hearth. Every 20 or 30 minutes a valve is moved, so as to alternate the flow.
SIEMEN'S-MARTIN PROCESS. The acid open-hearth process of making steel.
SILICA. A dioxide of silicon (SiO_2). It occurs in nature as quartz.
SILICIOUS. Having the nature of silica or pertaining thereto.
SILICON. A chemical element of the non-metallic order.
SINGLE SHEAR STEEL. Sheer steel. *See* Steel.
SKELETON-CONSTRUCTION. A framework of structural steel that sustains all the external loads or forces from the top of a building to the foundation.
SKELP. A strip of iron or steel prepared for making pipes and tubes.
SKIDWAY. A skid or form used for skidding heavy articles.
SLAB. A flat, relatively thin, mass of metal.

Bending slab. A plate of metal with holes punched in it for holding pin around which thin plates or bars may be bent to required shape.

SLAG. Cinder; the molten substance, other than the metal under treatment, consisting of acid or basic oxides which may be composed of the gangue of the ore combined with a flux (usually lime) in smelting operations; or of substances (usually lime and iron oxide) introduced for the purpose of effecting or assisting in the purification process.
SLING. A closed loop of wire, chain, or rope for convenient passing under a body and attaching to the hook of a derrick tackle for the purpose of hoisting.

Rope sling. A sling made of rope.

Snap. A tool used in field riveting to form the head of the rivet. It consists of a hammerlike head, on a handle, having one of its faces hollowed out to give the desired shape to the rivet head. By placing this on the hot metal and striking it with a sledge, the rivet end is forced to conform to the shape of the hollow. Also a spring catch as in a snap hook. To break suddenly with a short fracture.

Rivet snap. A tool used for forming the head of a rivet.

Snipping. Chipping off, as with a tool struck by a hammer; cutting off quickly with a pair of snips.
Snips. Small, stout hand shears used for cutting sheet metal.
Soaking Pit. A pit in which steel ingots are placed immediately after casting, so that the mass of the ingot may acquire a uniform temperature before rolling.
Spacer. An iron casting, usually spool-shaped with a hole through its axis, used to separate beams or girders when two or more of them are used to form a member.
Spacing Table. A movable table with a gage on one side, used in shops for multiple punching work.
Spacing Washer. A packing washer.
Span. The distance between two supports holding up a structure; the structure itself that rests on the supports, as a span of a bridge; to reach from one support to another by means of a structure.

Anchor span. In a bridge consisting of a series of cantilevers, the span that separates two cantilever arms of other spans.
Bascule span. The moving span of a bascule bridge.
Beam span. A span built with beams.
Cantilever span. That span of a cantilever bridge that contains a suspended span and either one or two cantilever arms. Sometimes the suspended span (most improperly) is omitted, making the cantilever span consist of two cantilever arms only.
Channel span. The span that bridges the deepest part of a river or that part most accessible for navigation.
Clear span. The distances between the two inside faces of the supports of a span.
Continuous span. A span that is supported on more than two piers or on more than one abutment and one pier and that distributes the load to the various supports on which it rests, or a series of consecutive spans effectively connected together over the points of support.
Deck span. One of the spans of a deck bridge.
Draw span. A movable span in a bridge over a navigable stream, to permit the passage of vessels.
Effective span. The distance from center to center of end pins in a bridge span, or that between centers of bearings in any structure.
Fixed span. A span that is not movable as opposed to a draw span.
Girder span. A span built of girders.
Half-through span. A span in which the deck is placed between the upper and the lower chords and where there is no overhead bracing.
Intermediate span. Any one of the spans between the end spans of a bridge.
Lift span. A span of a bridge that is raised for the passage of vessels.
Movable span. Any span of a bridge that may be moved in any manner to allow passage for vessels through or under the bridge.
Shore span. Either the first or the last span of a bridge.
Simple span. A span that rests on two supports, one at each end, and that does not affect the stresses in the adjoining spans.
Skew span. A span making an angle, other than a right angle, with the axes of the piers and abutments.
Spread span. A span at the end of a bridge so spread out at the shore that diverging tracks may be run thereon.
Suspended span. A span connecting two cantilever arms and supported wholly thereby.
Swing span. A span that revolves on a center pier or swings from an end pier to allow a passage for vessels through the bridge.
Through span. A span in which the traffic is carried between the trusses and which has lateral bracing in the plane of the upper chords.
Tower span. A span directly over and supported by a tower in a trestle or viaduct.
Truss span. A span supported by trusses.

Span Length. The distance from center to center of supports.

Clear span length. Clear span.
Effective span length. Effective span.

Spandrel. The space from abutment to abutment in an arch bridge extending from the top of the arch masonry to the top of the roadway.
Spandrel Beam. A beam extending from column to column and carrying an exterior wall load.
Spandrel Braced. In the form of a trussed arch, in which the top chord is horizontal and the bottom chord is arched.
Spiegeleisen. Pig iron that contains from 10 to 30% of manganese.
Splice. To unite two pieces firmly together; the parts used in making the union.

Butt splice. A splice formed by bringing the dressed square ends of two pieces of material together and joining them by welding or bolting or by riveting on plates or scabs.
Chord splice. A splice made in a chord of a truss.
Flange splice. A splice made in the flange of a beam or girder.
Full splice. A splice capable of developing the full strength of a member.
Lap splice. A splice made by placing one piece on top of another and fastening together with pins, nails, screws, bolts, rivets, or similar contrivances.
Partial splice. A splice that is capable of developing only a part of the resistance of a member.
Shingle splice. In a member composed of a number of component parts, such as one with compound web plates, a shingle splice consists in cutting all the said component parts at different but near-by locations and letting the splice plates extend over all the individual joints.
Web splice. A splice joining two web plates.

Sponge. Metal in a porous form.
Sponginess. The state or character of being soft, porous, or spongy.
Stability. The ability to resist change of position.

Moment of stability. The resistant moment of a structure due to its weight acting with a lever arm equal to the distance between its center of gravity and the edge of the structure about which it tends to rotate.

Stagger. To arrange in a zigzag order, as the staggering of rivets.
Stanchion. An upright post supporting a roof.
Static. Pertaining to or designating bodies at rest or forces in equilibrium.

STATICS. That branch of mechanics that deals with a balanced system of forces acting on bodies at rest.

Graphic statics. A method of resolving and combining forces, determining their resultant, its direction and point of application, shears, and bending moments by graphical processes.

STAY. A rope used to support a vertical pole or mast, such as a derrick mast; to support by means of stays.

Back stay. A rope or cable extending backward from the head of a mast and fastened to some permanent object; a rear cable in a suspension bridge running from the top of tower to the anchorage.

STAY PLATE. A batten plate. *See* Plate.

STEEL. A modified form of iron, not occurring in nature, made from pig iron by oxidizing most of the carbon.

Acid steel. Steel made without the use of lime.

Acid Bessemer steel. A metal produced by the decarburization of crude pig iron in a converter where finely divided air currents are blown through the molten mass. The lining of the converter is of a silicious material that will have no effect on the phosphorus, hence that element is not eliminated.

Acid open-hearth steel. A metal formed of pig iron, cast iron, and wrought iron or steel scrap, which is converted into steel by the direct action of an oxidizing flame in a regenerative gas furnace. The furnace is lined with a silicious material that has no effect on the phosphorus content.

Alloy steel. A steel carrying a certain portion of some other metal, such as nickel or vanadium.

Basic open-hearth steel. A metal formed of pig iron, cast iron, and wrought iron or steel scrap, which is converted into steel in a furnace having a lining of dolomitic limestone in order to resist the action of the slag. This slag contains much of the phosphorus in combination with calcined lime with which the furnace is charged. In this way the phosphorus content is reduced materially.

Bessemer steel. Steel made by the Bessemer process.

Blister steel. Steel made from wrought iron by heating it while in contact with some form of carbon.

Boiler steel. A medium steel rolled into plates from $\frac{1}{4}$ to $\frac{1}{2}$ in. in thickness and used for making boilers.

Bronze steel. An alloy of copper, tin, and iron used as gun metal.

Burning steel. A mechanical separation of the grains due to extreme overheating of steel.

Burnt steel. Steel that has been overheated in the making or remelting. It is coarse-grained and very brittle when either hot or cold.

Carbon steel. Ordinary steel that contains no other alloying element than the usual amount of manganese. The term is generally employed in contradistinction to nickel steel or other alloy steel.

Case-hardened steel. Steel with the outer skin hardened by heating, after being made into shape, with some such animal substance as grease, bone, hoofs, or horns.

Case steel. The outside skin on steel caused by case hardening.

Cast steel. Steel cast into shape directly from the furnace instead of being cast into ingots and rolled or melted.

Cemented steel. Steel produced by impregnating bars of wrought iron or soft steel with carbon at a temperature below the melting point.

Charcoal steel. Steel in the production of which charcoal is used for a fuel.

Chrome steel. Steel that usually contains 2% chromium and from 0.8% to 2% carbon. It is very hard and has a high elastic limit.

Cold-short steel. A steel that is very brittle when cold, usually owing to an excess of phosphorus.

Converted steel. Steel that has undergone a process of cementation in fire brick chambers or converting pots.

Crucible cast steel or crucible steel. Steel made by melting down in a closed crucible the various grades of iron or steel with or without the addition of carbon, ore, or other materials.

Double shear steel. Steel made by a process in which the shearing and welding described for single shear steel is repeated.

Fiery steel. Burnt steel showing very coarse, bright grains when fractured.

Gad steel. Flemish steel wrought from wedge-shaped ingots.

German steel. Steel made in Germany—an obsolete term.

Hard steel. Steel that has undergone the process of hardening; high steel.

Hardening of steel. Bringing the metal to the condition in which it is best able to resist abrasion or scratching. This is accomplished by heating the steel to a high temperature and cooling quickly, or by mechanical working.

High steel. Steel containing a comparatively large amount of carbon, from 0.5% to 1%.

Homogeneous steel. A steel solid and free from blow holes; a variety of crucible steel easily bent and worked.

Hot short steel. A steel that is very brittle when hot—usually owing to an excessive amount of sulfur.

Ingot steel. Steel run from the furnace into rectangular molds to be subsequently rolled or forged.

Low steel. A soft steel containing a small amount of carbon—less than 0.25%.

Manganese steel. Steel containing from 11% to 14% manganese and 1.5% of carbon. This is a very hard, brittle steel and has to be treated by cooling in water to remove the extreme brittleness—used where high resistance to abrasion is necessary.

Medium steel. Steel neither very hard nor very soft, containing from 0.25% to 0.5% of carbon.

Mild steel. A soft steel; low steel.

Mushet steel. A steel containing 1.5% of carbon and from 5 to 8% of tungsten which when hardened by air cooling holds its temper until it becomes red hot.

Nickel steel. Steel containing from 3 to 5% of nickel and from 0.2 to 0.5% of carbon. The addition of the nickel increases the strength and the elastic limit of the metal.

Open-hearth steel. Steel produced in a regenerative, reverberatory furnace where the hearth is open and exposed to the action of the flame.

Pipe in steel. A defect in the top of an ingot due to the shrinking of metal while cooling, thus leaving a cavity.

Puddle steel. A steel made by the puddling process in a reverberatory furnace in which the carbon is reduced at a low temperature to 0.5%. This process is seldom used nowadays.

Restoring steel. Treating burnt steel by heating and mechanically working the metal.

Rivet steel. A soft steel from which rivets are made.

Rolled steel. Steel that has been cast into ingots and then passed through a succession of rolls until the desired final shape is obtained.

Self-hardening steel. Mushet steel.

Shape steel. Shape.

Shear steel. Steel made in the form of bars by shearing blister steel into short lengths, piling these upon each other,

heating, and welding them by rolling or hammering into one piece.

Soft steel. Low steel; mild steel.

Temper of steel. Degree of hardness produced in high-carbon steel by water or oil treatment of cooling.

Tempered steel. Steel that has undergone the tempering process.

Tool steel. Steel that, by special treatment or peculiar composition with alloying metals, is adapted to retain a cutting edge at comparatively high temperatures so as to permit of high cutting speeds.

Tungsten steel. Steel usually containing from 5 to 10% of tungsten (sometimes as much as 24%) and from 0.4 to 2% of carbon.

Vanadium steel. An alloy steel containing a small percentage of vanadium which has the effect of raising the elastic limit and ultimate strength of the metal, mainly by purification.

Weld steel. Steel capable of being welded.

Wild steel. Steel that spits and flies in the ladle, usually caused by overoxidation of the metal.

STIFFENER. A secondary member, usually an angle, attached to a plate to prevent buckling.

End stiffener. Vertical angles riveted to the web of a plate girder at its ends for the purpose of stiffening it and transferring the end shear to the shoe or base plate.

Intermediate Stiffener. Any one of the stiffeners on a plate girder between the end stiffeners.

Web stiffener. An angle riveted to the web of a beam to distribute a load or to prevent buckling.

STOCK. The raw material used for charging a furnace.

STRAIGHTENING MACHINE. A machine used for straightening bars, beams, channels, etc.

STRAIN. The deformation caused by an external force applied to any piece of material or to any bridge member; often loosely used for stress.

Angular strain. Torsional strain.

Compressive strain. The deformation caused by a compression load; also called "shortening."

Crushing strain. An incorrect but rather common expression for the ultimate strength in compression.

Lateral strain. A deformation at right angles to the axis of the member.

Rate of strain. The ratio of the deformation to the original length of a member.

Shearing strain. The deformation produced by a shearing force.

Tensile strain. The deformation produced by an external tensile force; also called stretch or elongation.

Torsional strain. A deformation in a member caused by a twisting moment.

Transverse strain. A deformation caused by a force acting at right angles to the axis of a member.

STRAIN SHEET. Wrongly used for "stress sheet."

STRAW BOSS. A pusher.

STRENGTH. The capacity to resist distortion or disintegration.

Compressive strength. The capacity to resist compression.

Crushing strength. The ultimate power of a material to resist disintegration by crushing.

Proof strength. The greatest resistance that a body can offer to an external force without the stress exceeding the elastic limit of the material.

Shearing strength. The resistance that a body can offer to a shearing force.

Tensile strength. The resistance that a body can offer to an external tensile force.

STRESS. An internal distributed force that resists the change in shape and size of a body subjected to external forces.

Advancing load stress. A stress in a member induced by a load advancing on the structure.

Allowable unit stress. The allowable stress per unit of area given in the specifications.

Apparent stress. A term used to indicate that the stress has been determined by the principles of statics, and, therefore, ignores the effect of the lateral deformation of the member or that of secondary stresses.

Axial stress. A stress, either tension or compression, acting along and in the direction of the axis.

Balanced load stress. A stress in a member of a draw span induced by having both arms of the draw symmetrically loaded.

Bearing stress. The stress developed in a bearing by the superimposed load.

Bending stress. The stress produced in a member by a bending moment.

Bond stress. The longitudinal stress set up between the surface of a reinforcing bar and the surrounding concrete.

Breaking stress. The stress developed in a member at the point of rupture.

Buckling stress. A compressive stress so great that the elastic limit of the piece is exceeded, and, in consequence, a buckling or bulging of the material occurs.

Center of stress. The point of application of the resultant of the stresses on a section.

Centrifugal stress. A stress due to the centrifugal reaction of a live load moving in a curve; any stress acting in an outward direction from the center of a body.

Centripetal stress. Any stress acting toward the center of a body.

Chord stress. Any stress which exists in a chord of a truss.

Combined stress or compound stress. A union of stresses such as direct stress and bending.

Compressive stress. A stress that resists the shortening effect of an external compressive force.

Concentrated load stress. Stress induced in a member by concentrated loads on a structure.

Conjugate stress. Two sets of stresses each of which acts parallel to the plane upon which the other acts.

Counter stress. A stress in the web member of a truss which occurs for certain positions of the live load and is the reverse of the usual stress in the member or panel.

Crippling stress. The stress resulting in a member at the point of crippling; the stress necessary to cripple the member.

Cumulative stress. A stress that piles up in a member.

Dead-load stress. The stress resulting from the application of a static load; generally, the stress produced in a structure by its own weight.

Direct stress. A stress resulting from a direct application of the load.

Direct wind-load stress. Stress due to the wind load applied directly to the lateral trusses of a span.

Ellipse of stress. A relation between stresses such that if a pair of principal stresses, of the same or opposite kinds, be represented by the semi-major and semi-minor axes of an ellipse, respectively, the intensity of the stress in any direction in the same plane is represented by the semi-diameter of the ellipse in that direction.

Erection stress. Stress induced by loads applied during the erection of a structure.

Extreme fiber stress. In members subjected to bending, the intensity of stress on the fiber (or elementary strip) farthest removed from the neutral axis.

Fiber stress. The stress on an elementary fiber, strip, or element of a member.

Flange stress. The stress developed in the flange or flanges of a member.

Impact stress or impact load stress. Any stress caused by the sudden application of a load over and above that which the load at rest would produce.

Inch stress. A stress distribution on a square inch of area; the common unit of stress in metals.

Indeterminate stress. A stress that cannot be determined by the principles of statics.

Indirect stress. A stress induced by another stress.

Indirect wind stress. A stress due to a transferred wind load.

Induced stress. Indirect stress.

Initial stress. Stress put on a member before the regular loads are applied. This is accomplished by making the member a trifle shorter or longer than the required normal length and then forcing it into place in the structure, or by operating a turnbuckle after erection.

Intensity of stress. The stress per unit of area; also called "unit stress."

Internal stress. Any stress in a member.

Lateral stress. A stress that acts at right angles to the axis of a member through which tension or compression is produced; sometimes employed to mean the stress in a member of a lateral system.

Live-load stress. Any stress caused by the application of a moving load.

Longitudinal stress. Stress parallel to the axis of a member.

Main stress. Direct stress.

Maximum stress. The greatest stress that comes on a piece, or sometimes the greatest stress a member can have with its allowable load.

Normal stress. A stress that acts at right angles to a plane in the interior of a body.

Primary stress. Main stress.

Principal stresses. Conjugate stresses that are at right angles to each other.

Pure stress. A term used for cases where only one kind of stress exists.

Range of stress. The limits between which the stress or stresses in a member vary as the load changes.

Repeated stress. A stress due to a load which is applied to and removed from a body a great number of times.

Resultant stress. The stress resulting from combining all the stresses that act on a piece simultaneously.

Reversal of stress. The changing of stress from tension to compression, or vice versa.

Secondary stress. An indirect stress set up by the deformation of a member caused by primary stresses.

Shearing stress. A stress that resists any action tending to slide one part of a body past an adjacent part.

Static stress. Dead-load stress—stress due to a quiescent load.

Sudden stress. The stress resulting in a member from the sudden application of a load thereto.

Tangential stress. A stress that acts along a plane in the interior of a body.

Temperature stress. A stress due to the contraction or expansion of a body from changes in temperature.

Tensile stress. A stress resisting the elongation of a body.

Torsional stress. The stress arising from the deformation set up by a torque or twisting moment.

Total stress. The sum of all the stresses at a section of a body.

Traction stress. A stress caused by the thrust of a braked train due to the friction of the wheels on the rails when skidding, or by the horizontal effort of the locomotive wheels against the rails.

Transferred load stress. The stress in a member caused by the transferring of a load from another member.

Transverse stress. A stress at right angles to the axis of a member.

True stress. A stress as measured by the deformation as it actually occurs.

Ultimate stress. The greatest stress that can be produced in a body before rupture occurs.

Uniform load stress. A stress resulting from the application of a load uniformly distributed over the structure.

Uniform stress. A stress that has a uniform intensity throughout its area of action.

Uniformly varying stress. A stress, the intensity of which varys as its distance from a fixed point.

Unit stress. The stress per unit of area; the measure of intensity of stress.

Uplift stress. A stress due to an uplift action, as that from the end lifting machinery in a swing span.

Vibratory stress. A stress caused by vibration.

Web stress. Any stress in a web member of a truss.

Wind stress. A stress caused by the application of a wind load to the structure.

Working stress. The allowable stress on any piece as provided in the specifications; carelessly used for "working unit stress."

Working unit stress. The allowable unit stress or intensity on any piece as provided in the specifications.

STRESS SHEET. Stress diagram. *See* Diagram.

STRING POLYGON. An equilibrium polygon. *See* Polygon.

STRING. A longitudinal member extending from panel to panel of a bridge and supporting the ties or the flooring.

Chord stringer. A chord length subjected to bending as well as to direct stress.

Continuous stringer. A stringer that extends over two or more panels.

Jack stringer or outside stringer. A stringer placed outside the line of main stringers.

Track stringer. A beam or girder carrying a track.

STRUCTURE. A general term for anything that is built or constructed, as a bridge or a building.

Granular structure. A granular condition of iron or steel, shown in its fracture, caused by overheating in the furnace.

Substructure. The part of any construction that supports the superstructure.

Superstructure. The part of a structure that receives the live load directly.

STRUT. A bridge member carrying compression.

Angle strut. A strut built up of angle irons.

Box strut. Any strut built of structural shapes having a box-like cross section.

Channel strut. A strut built up of channels.

Collision strut. A strut placed against a point a little below the middle of the inclined end post of a bridge so that, in case of a derailment or a shifted load striking the end post,

the shock will be carried longitudinally to other members and not be taken up in bending by the end post.

Counter strut. A web member subject to both compression and tension.

Horizontal strut. A compression member lying in a horizontal position.

Inclined strut. A compression member placed in an inclined position.

Intermediate strut. An overhead strut in high bridges attached to the posts of opposite trusses and lying between the upper lateral strut and the floor. In deck bridges, if used at all, it would be between the upper and the lower lateral struts.

Laced strut. A strut that has lacing of small bars running diagonally on the open face or faces.

Lateral strut. A strut in the lateral system of a bridge.

Overhead strut. A strut in the overhead portion of the sway bracing of a bridge.

Pedestal strut. A strut connecting and bracing two pedestals.

Portal strut. A strut in the portal bracing of a bridge.

Radial strut. One of a series of struts radiating from a fixed point, as the spokes of a wheel, or the radial braces of a turntable, or a swing-span drum.

Secondary strut. A secondary member taking up compression.

Star strut. A strut formed of either two or four angles placed back to back. The two-angle form is not a satisfactory type, as it fails to develop as high an ultimate strength as might properly be anticipated.

Stiffening strut. A strut used to overcome a buckling tendency or to fix an intermediate point of a post or column and thus reduce the value of l over r.

Substrut. A subdiagonal carrying compression.

Sway strut. A strut used in sway bracing.

Timber strut. A strut made of timber.

Vertical strut. A vertical compression member.

SUBDIAGONAL. A secondary member connecting the midpoint of a main diagonal with an adjacent panel point.

SUSPENDER. A hanger used to suspend a floor from a cable or from a truss or other object.

SUSPENSION ROD. One of the rods attached to the cable of a suspension bridge for the purpose of supporting the floor.

SWAY. To brace laterally or longitudinally against horizontal movement.

SWEATING. A method of fastening two metallic surfaces together by means of a very thin invisible layer of solder.

SWELLED COLUMN. A column that is larger at the middle than at the ends.

SWIPE. To strike or drive with great force.

SYENITE. A rock composed of feldspar and hornblende with very little or no quartz.

SYMMETRY. A condition of equality or balance of shape, size, and position between similar parts of a figure or body about a central axis.

Axis of symmetry. A line about which the parts of a figure or body are symmetrically disposed.

Center of symmetry. The intersection of the axes of symmetry.

Plane of symmetry. A plane about which the parts of a figure or a body are symmetrically disposed.

T-IRON. Tee iron. *See* Iron.

TANGENT. A straight line passing through two consecutive points of a curve.

TAP. A tool for cutting threads in a hole.

TEMPER. To bring a metal, such as steel, to a proper degree of hardness; the condition of steel relative to the degree of hardness.

TEMPERING. The act of producing a temper in steel or other metal.

Oil tempering. A process of plunging red-hot steel into oil to harden it; a term frequently used for oil hardening because the effect on the steel is similar to that of quenching in water and then drawing the temper by a subsequent application of a moderate heat.

Water tempering. A process of heating hardened steel to draw the temper (lower the degree of hardness) and quenching in water when the desired condition (as indicated by the color) is attained.

TEMPLET OR TEMPLATE. A full-sized pattern, generally made of wood and used to lay off work in fabricating shops.

TENACITY. That property of a body by which it resists being pulled apart.

TENSILE. Pertaining to tension; the character of the force that tends to separate, in the most direct manner possible, the adjoining parts of a body.

TENSILE STRENGTH. Tensile resistance.

TENSION. The state or condition of being stretched.

Direct tension. Tension applied parallel to the axis of the member and uniformly over its cross section.

Initial tension. Tension applied to a member before it is subjected to the principal load.

TEST. A method for determining the properties of a material; the act of testing.

Bending test. A test made by bending bars to determine their comparative brittleness; a test made on beams to determine their moduli of rupture.

Specimen test. A test of a portion of the material to be used in the construction of a structure.

TEST PIECE. A piece, portion, or specimen of any material used for testing or determining its qualities and properties.

TESTING MACHINE. A machine provided with the mechanism for exerting a force on a specimen of some material and thereby determining its properties.

THRUST. To push; the amount of push.

Horizontal thrust. A thrust in a horizontal direction, as that of a braked train.

Longitudinal thrust. A thrust along the longitudinal axis of a member.

TIE. A tension member of a truss.

Diagonal tie. A tension diagonal incapable of resisting compression.

TILT. To forge with a tilt hammer.

TIT. A small accidental projection on a casting; spelled also "teat."

TOGGLE. A mechanical device consisting of two bars or plates hinged together at their common ends and pivoted at the other ends—used for transmitting a force laterally to its line of application.

TON. A unit of weight, generally equal to 2,000 lb.

Foot-ton. A unit of work equal to that involved in overcoming 1 ton of resistance through the space of 1 ft., or in raising 1 ton 1 ft.

Inch-ton. A unit of work equal to that involved in raising 1 ton 1 in.

Long ton. A unit of weight equal to 2,240 lb., generally employed for coal and steel rails. It is the English ton.

Metric ton. A French ton, equivalent to 2,205 lb. nearly.

Short ton. A ton of 2,000 lb.

TON-FOOT. A foot-ton.

TONGS. A tool for grasping objects, consisting of two flat, curved bars pivoted about a common center.

Hammer tongs. A pair of tongs designed for picking up the red-hot handles of tools or hammer heads.

Rivet tongs. Tongs used by riveters for throwing and placing hot rivets.

TOOL. Any thing, device, or apparatus used to facilitate mechanical operations; usually restricted to small implements.

Balling tool. A hand tool used for collecting into a mass the iron in a puddling furnace.

Calking tool. A tool used for the process of calking.

Cutting tool. A tool used for cutting materials.

Heading tool. A tool for the swaging of bolt heads.

TORQUE. The moment of a force or a system of forces tending to produce rotation; the starting capacity of a rotative machine.

TORSION. The twist or deformation of a body set up by a torque.

Angle of torsion. The amount of twist or deformation produced by a torque.

Coefficient of Torsion. The angle of torsion produced in a wire of unit dimension by a force acting with unit moment.

Moment of Torsion. The sum of all the moments of the internal forces in a body that is resisting a twisting moment. It is equal to the sum of the moments of all the applied forces that tend to produce torsion.

TOWER. A vertical structure consisting of two or more bents of framework connected by bracing.

TRACING. A drawing made on transparent cloth; the act of copying on tracing cloth a drawing placed beneath.

TRACING CLOTH OR TRACING LINEN. A fine linen fabric covered with a gelatinous material or sizing, making it transparent so that it can be used for copying drawings.

TRACTION BRACING. Train-thrust bracing. *See* Bracing.

TRACTION THRUST. Traction load. *See* Load.

TRANSVERSE. Extending across; crosswise direction.

TRAVELER. A form of derrick mounted on wheels, used in the erection of bridges.

Creeper traveler. A small movable derrick running on a track on the upper chord of a truss usually having two booms; a mule traveler.

Gantry traveler. A framework of two or three bents or gallows frames, braced longitudinally and carried on a track supported on falsework and placed outside the trusses. The traveler clears the span at all points and can be rolled back and forth as needed. It carries a number of blocks and tackles operated by a hoisting engine placed on a platform near the base. It is used in erection for hoisting and placing the members of a truss.

TRESTLE. A bridge structure composed of bents or towers and supporting stringers or girders forming the floor system.

Framed trestle. A trestle having framed bents.

Knee-braced trestle. A trestle provided with knee braces.

TRUSS. A framed or jointed structure designed to act as a beam while each of its members is primarily subjected to longitudinal stress only.

A-truss. A four-panel truss having extended batter posts intersecting over the center resembling somewhat the letter A.

Arch truss. A truss having an arched upper chord in compression and a straight bottom chord or tie rod with vertical hangers.

Baltimore truss. A truss composed of parallel chords and subdivided panels.

Bollman truss. A trussed beam, each panel load being carried directly to the ends of the upper chord by two inclined tension members, there being no stress in the lower chord. Properly speaking, it is not a truss, but a multiple suspension system.

Bowstring truss. A truss in which the lower chord is horizontal and the upper chord joints lie in the arc of a parabola, or similar curve.

Bridge truss. Any truss used in a bridge span.

Burr truss. A timber truss with counterstruts inserted throughout the entire length, giving very great rigidity.

Camelback truss. A truss having a broken outline for the upper chord taking the humped shape of a camel's back.

Cantilever arch truss. A cantilever truss having the shape of a portion of an arch.

Cantilever truss. A truss overhanging its support at one end and anchored down at the other.

Continuous truss. A truss that extends over three or more supports.

Crescent truss. A truss with both chords curved upward, or both downward, and making sharp intersections with each other at the ends, producing in outline the appearance of a crescent, the web system being of the triangular type.

Deck truss. A loose expression for the truss of a deck span.

Double bowstring truss. A truss in which the joints of each chord lie in curves concave to each other.

Double intersection truss. A truss having two intersecting diagonals for each panel.

Double triangular truss. A double intersection truss.

Fink truss. Properly, a trussed beam.

Half-through truss. A loose expression for the truss of a half-through span.

Hog-chain truss. Properly a trussed beam; an inverted queen post truss.

Horizontal truss. A truss placed in a horizontal plane.

Howe truss. A form of truss in which the vertical members of the web take tension and the diagonal members compression.

Intermediate truss. The center truss of a three-truss span.

K-type truss. A truss in which the panel arrangement is similar to the letter K.

Kellogg truss. A variation of the Pratt truss.

King post truss or king truss. Properly a trussed beam with one vertical post at center.

Lattice truss. A truss having several web systems.

Lenticular truss. A double bowstring truss.

Linville truss. A Whipple truss.

Multiple truss. A truss having a multiple cancelation web system.

Murphy truss. A Whipple truss having eyebars for the lower chords.

Palmer truss. A Burr truss.

Parabolic truss. A bowstring truss having the upper chord joints lying in a parabola.

Parker truss. A name sometimes used for the Pratt truss when the upper chord is polygonal.

Pegram truss. A form of truss having the panel points of the upper chord lying in the arc of a circle and inclined web members.

Pennsylvania truss. A Petit truss with an inclined chord.

Petit truss. A modified form of the Pratt truss having subdiagonals.

Pin-connected truss. Any truss having its main members joined by pins.

Pony truss. A low truss without any overhead bracing.

Pratt truss. A type of truss having parallel chords and an arrangement of web members of tension diagonals and compression verticals.

Primary truss. A main truss that supports smaller trusses.

Quadrangular truss. A Pratt truss.

Queen post truss. A type of trussed beam having two vertical posts.

Riveted truss. Any truss having its main members riveted together.

Roof truss. Any truss used in supporting a roof.

Schwedler truss. A modification of the Whipple truss.

Secondary truss. A truss supported by another truss.

Single-intersection truss. A truss with one web system only.

Stiffening truss. A truss used in connection with a suspension cable to distribute the load over the length thereof.

Subdivided Warren truss. A Warren truss with verticals having subdiagonals and subverticals.

Through truss. A loose expression for a truss of a through span.

Town truss. A form of lattice truss having double chord systems and two web systems in different planes.

Triangular truss. A truss having inclined web members.

Truncated bowstring truss. A bowstring truss with squared ends.

Warren truss. A form of triangular truss composed of equilateral triangles.

Whipple truss. A double-intersection Pratt truss.

Wind truss. A truss to carry a wind load.

TRUSS MEMBER. Truss element. *See* Element.

TRUSS SHOP. A shop where bridge trusses are manufactured.

TRUSS SPACING. The perpendicular distance between the central planes of trusses of a bridge.

TRUSSED ARCH. A braced arch. *See* Arch.

TURNBUCKLE. A device for tightening or drawing together two parts of a rod, consisting of a sleeve having an interior right-hand thread at one end and an interior left-hand thread at the other. This sleeve engages the threaded ends of the two pieces of rod so that a turning thereof in one direction screws up on the rods and in the reverse direction unscrews on them.

TUYÈRE. A tube or pipe through which air is blown directly into a blast furnace.

TWO-BLOCKS. An expression used by bridge erectors in hoisting to signify that a stopping point or limit has been reached; derived from the condition of a block and tackle being overhauled until the two blocks come together when no further motion in the same direction is possible. A synonym is "chock-a-block."

ULTIMATE STRENGTH. Ultimate resistance.

UNIFORM STRENGTH. Uniform resistance.

UNSUPPORTED WIDTH. The width of a plate between the nearest points of lateral restraint.

VERTICAL. An upright member in a truss.

Hip vertical. The upright tension member attached to the pin or to the plates at the hip of a truss and carrying a floor beam at its lower end.

Subvertical. The upright member in a subdivided panel running from midpanel point to the chord.

Viaduct. An extended bridge of many spans, mainly over dry ground; usually consists of alternate towers and open spaces or bays.

VIBRATION. A movement back and forth; a form or mode of motion in which the moving particle occupies successive positions in recurrence.

Amplitude of vibration. The maximum movement or displacement of any particle that vibrates.

Cumulative vibration. A piling up or a superposing of vibration; an increasing vibration.

Period of vibration. The time required for the vibrating particle to make one complete movement back and forth.

VIRTUAL VELOCITY. An arbitrary, infinitesimal displacement of the point of application of a force resolved into the line of action of the said force. The term is a misnomer, for it has nothing whatsoever to do with velocity.

WEB. The portion of a truss or girder between and connecting the flanges, its function being principally to resist shear.

Open web. A web composed of a group of members instead of solid plates.

Solid web. A web composed of one or more solid plates.

WELD. To unite two pieces of metal by fusing them together; the part of the piece thus united.

Butt weld or jump weld. A weld in which the pieces are butted against each other and then joined by welding.

Lap weld or scarf weld. A weld in which the ends of the pieces are made to lap over each other and then joined by welding.

WILLIOT DIAGRAM. A graphical method for determining the deflections of a framed structure.

WOHLER'S LAWS. A series of laws based on Wohler's experiments on the fatigue of metal. It is now conceded that they do not in any way apply to structural designing, because they deal solely with metal stressed beyond the elastic limit and are not applicable otherwise.

WORK OF RESILIENCE. The work done by a deformed elastic body in recovering its normal condition. Theoretically, this is equal to the energy stored in the body during its deformation, provided that the elastic limit of the material has not been passed.

WRENCH. A tool for turning nuts, bolts, and pipes, consisting of a bar or handle having jaws to fit the nut, bolt, or pipe.

Alligator wrench. A wrench with fixed spreading jaws, having an inside roughened surface, suggestive of the open mouth of an alligator.

Claw wrench. A wrench with a claw end.

Combination wrench. A wrench having jaws to fit both nuts and pipes.

Diagonal wrench. A wrench in which the axis of the jaws is set obliquely to the handle.

Double wrench. A wrench having a set of jaws at each end.

Forked wrench. A wrench having a pair of jaws at one end of a bar, while the other end tapers to a point.

Key wrench. A socket wrench having a cross handle; also a wrench having one sliding jaw held in place by a key.

Monkey wrench. A wrench having an adjustable jaw moved by a screw.

Open-end wrench. A forked wrench.

Pipe wrench. A wrench having its jaws shaped and adapted for holding a pipe.

Ratchet wrench. A wrench provided with a handle engaging a ratchet.

S-wrench. A wrench having a bent handle like the letter S.

Socket wrench. A wrench having a handle and shank with a recess in the shank to fit the nut.

Tap wrench. A cross-handled wrench used for turning a tap.

YIELD POINT. That point, or intensity of stress, at which the rate of stretch begins to increase rapidly.

YOUNG'S MODULUS. The modulus of elasticity. *See* Elasticity.

ZIGZAG RIVETING. Staggered riveting.

SURVEYING *

Although there is some confusion as to the meaning of certain terms used in surveying, especially in the newer fields, and in cases where more than one term is used to mean the same thing, the following terms and definitions are adopted as the best usage. Those terms whose meanings are obvious have purposely been omitted.

ACCURACY. Nearness to the truth. It embodies the notion of care, or painstaking, and is not to be confused with precision. Example: A measured length read to thousandths of a foot is more precise than if read to hundredths of a foot only. However, if the first measurement contains an error of several hundredths, due, for example, to failure to allow for erroneous length of tape, or to uncorrected temperature error, it may be much less accurate than the second, if in the latter an attempt has been made to correct for these errors. (In estimating the accuracy of the results of measurement, all sources of error should be examined and the total possible error estimated. Errors of the constant or systematic type are particularly important, as they are not revealed by repetition of a measurement; some of them, moreover, are not revealed by error of closure.) *See also* Precision.

AIR BASE. Aerial photographic mapping: The distance between the exposure stations of two overlapping aerial photographs. *See also* Base line.

ALINEMENT (ALIGNMENT). (1) Formation or position in line, or, more properly, in a common vertical plane. (2) Railway or highway surveying: The ground plan, showing the alinement or direction of the route to be followed, as distinguished from a profile, which shows the vertical element.

ANGLE. Difference in direction.

Angle to the right. Horizontal angle measured clockwise from the preceding line to the following one.

Deflection angle. Horizontal angle measured from the forward prolongation of the preceding line, right or left, to the following line.

Interior angle. Horizontal angle between adjacent sides of a polygon, measured within the polygon.

Vertical angle. Angle of elevation or depression, measured from the true horizontal plane.

ATTRACTION, LOCAL. Effect on the horizontal direction of the compass needle produced by the proximity of magnetic materials or electrical currents. Attraction is the same in principle as what is called deviation by navigators.

AZIMUTH (OF A LINE OR A DIRECTION). Angle between the plane of the meridian and the vertical plane through the given line; or, the horizontal angle to the right from the true south to the line or direction in question.

Astronomic azimuth. Same, when the horizon is perpendicular to the direction of gravity.

Geodetic azimuth. Same, when the horizon is perpendicular to a normal to the spheroid.

Plate azimuth. Aerial photographic mapping: The azimuth of the principal plane on the ground coordinate system. (In mapping operations, the United States Army measures azimuth from the north point. The Coast Artillery uses the south point for triangulation, but the north point in other instances. The United States Navy uses the north point. The United States Coast and Geodetic Survey and the United States Geological Survey use the south point.) *See also* Bearing.

BACK FOCAL DISTANCE. Photography: The distance between the rear focal plane of a lens and the rear surface of the lens, measured along the lens axis. (This term is not synonymous with either focal length or principal distance.)

BACKSIGHT. (1) Transit traverse: A sight on a previously occupied instrument station. (2) Leveling: The reading on a rod that is held on a point of known elevation, and which is to be used for computing the height of instrument. (A backsight is often called a plus sight, because it is added to the elevation of the point to obtain the height of instrument. It is not, however, essentially a positive quantity; for example, when the rod is held inverted on points overhead, as in mine and tunnel surveying, the reading is negative. The term "plus sight" is recommended as preferable; but the older term "backsight" is still in general use.)

BALANCING A TRAVERSE. Adjusting the observed measurements to conform to the geometrical requirements of the traverse. Balancing involves: (*a*) Distributing the angular error of closure so that the initial and final azimuths are in agreement, or so that the algebraic sum of the angles equals its theoretical amount: for example, 360° in the case of deflection angles, or $(n - 2)\ 180°$, in the case of interior angles; (*b*) distributing discrepancies in latitude and departure so that the algebraic sum of the latitudes and the algebraic sum of the departures each becomes zero (if the traverse closes on itself), or some known amount (if the traverse is run between two fixed points, such as triangulation stations).

BASE LINE. (1) Triangulation: A line forming one side of a triangle (usually in a connected series of triangles), and measured with great accuracy, from which all other distances are calculated; a "base" may consist of two or more lines ("broken base"), although in accurate work this is not desirable. (2) Traversing: The main traverse running through the site of proposed construction, from which property lines, street lines, buildings, etc., are located and plotted on the plan. (This is probably not a correct use of term; it is not recommended.) (3) Construction: The center line of location of a railway or a highway, often called "base line of location"; a reference line for the construction of a bridge or other structure. (4) Public land survey: The parallel of latitude established through the initial point of a system of coordinated township boundary lines. (5) Aerial photographic mapping: *See* Air base.

BEARING. (1) Horizontal angle between the meridian (true or magnetic) and any specified direction. The angle is measured from either the north or the south point, as may be required to give a reading of less than 90°, and the proper quadrant is designated by the letter N or S, preceding the angle, and the letter E or W, following it; as, N 80° E. ("True bearings" are measured from the geographic meridian; "magnetic bearings," from the local magnetic meridian. In navigation, bearings greater than 90° are used. In early documents of record, bearings counted from the east or west point will be found.) (2) Land surveys, Texas: A reference point or witness to identify a land corner or a point on a survey line.

BENCHMARK. A relatively permanent point of known or assumed elevation.

CADASTRAL MAP. A map showing the extent, ownership, value, etc., of land. In the United States, cadastral maps usually show individual tracts of land, with corners, length and bearing of boundaries, acreage, ownership, and, sometimes, cultural and drainage features. *See also* Map; Plat.

* From "Manual of Engineering Practice," Am. Soc. C. E.

Cadastral Surveys. Surveys relating to land boundaries and subdivisions, made to create or to define the limitations of titles, and to determine units suitable for transfer. The term includes surveys involving retracements for the identification, and resurveys for the restoration, of property lines. (The term "Cadastral" is practically obsolete; use "land survey" or "property survey.")

Center (of Transit). (1) Manufacturer's term for either of the two vertical spindles (axes) of the transit. The outer (hollow) center revolves in a socket and is attached to the graduated horizontal circle. The inner center revolves in a socket in the outer center and is attached to the alidade or upper portion of the instrument. (2) The common point of intersection of the vertical axis, the horizontal (cross) axis, and the axis of the telescope tube.

Center, Reduction to. Triangulation: The computation of the necessary corrections to allow for an eccentric set-up (that is, a set-up in which the instrument does not occupy the point under signal).

Chart, Nautical. A representation on a horizontal plane, and according to a definite system of projection, of a portion of the navigable waters of the earth, including the shore lines, the topography of the bottom, and aids and dangers to navigation; it may be derived from hydrographic, topographic, or aerial surveys, or a combination thereof.

Chord. Public land surveys: The line of a great circle connecting any two selected corners on a base line, standard parallel, or latitudinal township boundary.

Long Chord. Railroad or highway surveying: (1) Any chord (of a circular curve) longer than 100 ft.; (2) the chord that extends from the point of curvature to the point of tangency.

Closing the Horizon. Measuring, at a triangulation station, the horizontal angles between successive stations around the horizon so as to return to the starting point (the sum of the angles should equal 360°); measuring the last angle of the series, closing on the starting point.

Closure, Error of. (1) Of a traverse: The amount by which the computed position of the last point of the traverse fails to coincide with the initial point; that is, the length of line necessary to close the traverse. Frequently, also, the ratio of the linear error of closure to the perimeter (also known as the "error of the survey"). (2) Of angles: The amount by which the sum of the measured angles fails to equal the true sum. (3) Of azimuths: The amount by which the measurement of the azimuth of the first line of a traverse, made after completing the circuit, fails to equal the initial measurement. (4) Of a level circuit: The amount by which the last computed elevation fails to equal the initial elevation; or the amount by which the differences of elevation in a circuit fail to add up (algebraically) to zero. (5) Of horizon: The amount by which the sum of the angles measured around the horizon differs from 360°. (6) Of a triangle: The amount by which the sum of the three angles of a triangle differs from the true sum; that is, 180° + the spherical excess.

Collimating Marks. Photographic mapping: Index marks to define the x and y coordinate axes and the principal point of the photograph. These marks are registered on the negative either by metal points in the frame of the camera or by marks engraved on the pressure plate.

Collimation Position. The ideal position of the line of sight of a telescope; that is, the optical axis. *See also* Line of sight.

Collimator. A telescope, often without an eyepiece, that defines a fixed line of sight; used for adjusting transits and levels. The cross hairs, ruled lines, or other marks are set in the principal focal plane of the objective so that the rays from these marks emerge from the objective in a parallel beam. The telescope of the transit or level, when sighting into the collimator, must be focused for long distance. The collimator point is then optically equivalent to a point at an infinite distance.

Vertical collimator. An instrument in which the telescope sights vertically (upward or downward); used chiefly for centering a theodolite on a tower exactly over a station mark on the ground. It may be used for any vertical sight.

Comparator. Photographic mapping: A device for measuring accurately the two rectangular coordinates of the image of a point on a photograph.

Comparator Base. A carefully measured horizontal distance, usually one tape-length long, used as a means of checking and comparing the tapes used in the field.

Concluded Angle. Triangulation: The third angle of a triangle, not measured, but calculated from the other two angles.

Conjugate Center. Aerial photography: The image point on a photograph of the principal point of an adjacent overlapping photograph.

Contour Line. A level line connecting points on the surface of the earth having the same elevation; also, its representation on a map. It is the line of intersection of a level surface with the surface of the ground, as, for example, a shore line. Contour lines form closed loops which may or may not appear entirely within the limits of the map.

Control. Points on the ground, accurately fixed in position horizontally or vertically (or both), which are used as accurate starting and closing points for traverses, plane-table surveys, terrestrial or aerial photographic surveys, etc. A system of control points is usually established by triangulation or traverses, and by leveling.

Cadastral control. The established monuments whose positions are used in all correlated cadastral surveys.

Convergence of Terrestrial Meredians. (1) The angle between the meridians of two places; (2) the difference in the azimuth or the bearing of a line, AB, as measured from the meridian through A and as referred to the meridian through B.

Coordinates. Linear or angular dimensions designating the position of a point in relation to a given reference frame.

Astronomical coordinates. Latitude and longitude as observed astronomically.

Geodetic coordinates. Latitude and longitude as calculated on the spheroid.

Plane or rectangular coordinates. The perpendicular distances of a point from a pair of rectangular coordinate axes.

Plate Coordinates. Photographic mapping: Rectangular coordinates measured on a photograph with reference to the principal point as origin.

Space coordinates. Photographic mapping: The three coordinates of a point defining its horizontal position and elevation with reference to some system of ground coordinates.

Spherical coordinates. (1) The linear distances along the circumferences of two great circles which are at right angles to each other, measured from the point where their circumferences intersect; one coordinate is measured along the circumference of the first great circle to the intersection of this circumference and a third great circle plane passing through the point and perpendicular to the first great circle, and the second coordinate is measured

along the circumference of the second great circle to the intersection of this circumference and a plane passing through the point and parallel to the plane of the first great circle. (2) Latitude and longitude; coordinates similar to those just described except that the reference figure is an ellipsoid of revolution (the earth) instead of a sphere.

CORNER. A point determined by the surveying process, usually at the intersection of two or more lines.

CORRECTION. The amount to be added (algebraically) to any measured value to obtain the true value (or an improved value). The sign is opposite to that of the error. It is taken in the sense: correction = true value − measured value. (Example: A distance taped at a temperature below standard [68° F.] with a tape having a positive coefficient of expansion requires that, say, 0.04 ft. be subtracted from the result of the measurement. The correction is, therefore, −0.04 ft. the error is +0.04 ft.) *See also* Error.

CROSS SECTION. (1) A vertical section of the surface of the ground, or of underlying strata, or both, taken at right angles to the center line or across a stream; (2) a horizontal grid system laid out on the ground for determining contours, quantities of earthwork, etc., by means of elevations of the grid points.

CULTURE. Those features of the terrain that have been constructed by man, such as roads, trails, buildings, and canals; also, boundary lines and all names and legends.

CUT. Depth to which material is to be excavated (cut) to bring the surface to a predetermined grade; the difference in elevation of a surface point and a point on the proposed subgrade vertically below it.

DATUM. (1) Leveling: Any level surface taken as a surface of reference, from which to measure elevations; for example, mean sea level. Often spoken of as a "datum plane." The actual elevation of a datum above or below mean sea level may be unknown, but the datum can still be used as a surface of reference. In ordinary leveling it is assumed that all such surfaces are parallel to each other. A datum defined by "mean high water" or "mean low water" is actually a level surface, the elevation of which depends upon tidal observations at a given place; it does not necessarily agree with high or low water at any other place. (2) Geodesy: The basis for the computation of geodetic latitude and longitude, consisting of (*a*) an adopted latitude and longitude for (*b*) a selected station on a given spheroid, together with (*c*) a specified azimuth to an adjoining triangulation station. It may also include (*d*) specified methods of calculating the positions and azimuths. (Example: The North American Datum specifies the latitude and longitude for the station, Meade's Ranch (Kansas), on the Clarke spheroid of 1866 and also the azimuth to the station, Waldo. All geodetic positions on the American continent depend upon this position. The "North American Datum of 1927" specified that Laplace azimuths shall be used.) (3) Photographic mapping: The assumed horizontal plane on which the map is constructed.

DECLINATION. (1) Horizontal angle between the (magnetic) axis of the magnetic needle and the true, or geographic, meridian. (This angle is called "Variation of the Compass" by navigators.) (2) Angular distance of a celestial object, north or south of the celestial equator, measured by the arc of a great circle (that is, at the center of the earth) in a plane perpendicular to the equator.

DEFINITION. Photography: Sharpness of image.

DEFLECTION OF PLUMB LINE, LOCAL. The angle between the actual direction of the plumb line and that of the normal to the spheroid that represents the figure of the earth. (Sometimes called "station error.")

DEGREE OF CURVE. The number of degrees at the center of a circle subtended by a chord of 100 ft. Occasionally, in highway surveying, it is defined as the central angle subtended by an arc of 100 ft.

DEPARTURE. The length of the projection of a traverse course on a line perpendicular to the meridian (length of course times sine of bearing). (Called also "easting" or "westing.")

DIAPHRAGM. (1) The cross-hair ring or metal piece holding the cross hairs or spider lines in a telescope. (Also called reticule.) (2) Photography: A device for controlling the amount of light passed by a lens and for cutting out such rays as would tend to mar the perfection of the image. (Also called the "stop.")

DIRECTION. Angle to the right (clockwise) from an arbitrary zero direction. (Used chiefly in triangulation.)

DISCREPANCY. The difference between results of duplicate measurements.

DISPLACEMENT. Aerial photography: The horizontal displacement of the image of a ground point on a vertical aerial photograph due to the elevation of the point above or below the assumed ground plane. If no tilt exists it is radial from the principal point of the photograph; in a tilted photograph it is radial from the nadir point. Example: The vertical corner of a tall building is shown as a line, the top of the building being farther from the center of the picture than the base of the building. In an untilted photograph, this line, prolonged, passes through the principal point.

DISTORTION. Aerial photography: Deformation of images caused by tilt. If there is tilt but no relief, displacements are radial from the isocenter, and their magnitudes depend on the angle and direction of tilt. If both tilt and relief exist, the combined displacements are not radial from any single point.

Film distortion. Photography: Errors in direction, scale, and shape, caused by failure of film to lie flat in the camera, or by unequal contraction or expansion following exposure.
Lens distortion. Photography: Errors in position of photographic images caused by an improperly corrected lens.

DOUBLE MERIDIAN DISTANCE. The sum of the perpendicular distances from the two ends of any line of a traverse to the initial, or reference, meridian.

DRIFT. Aerial photography: Apparent rotation of aerial photographs with respect to the true line of flight, caused by failure to orient the camera to compensate for the angle between that line and the direction in which the airplane is heading.

ECCENTRIC SIGNAL. Triangulation: Signal placed at some point other than directly over the triangulation station, and not in line with the station and the instrument.

ECCENTRIC STATION. Triangulation: Point where an instrument is placed for the measurement of horizontal angles when it is not practicable to set up directly over the actual station.

ECCENTRICITY OF CIRCLES. (1) Failure of the inner center, or the inner vertical axis, of a transit to coincide with the center of the graduated circle; (2) the amount by which the two fail to coincide, expressed as seconds of arc on the circle.

ELEVATION. Vertical distance above or below datum to point in question.

ERROR (OF A SINGLE MEASUREMENT). The difference between a measured value and the true value. The algebraic sign is opposite to that of the correction; it is taken in the sense: error = measured value − true value. *See* Correction.

Error of traverses. *See* Closure, error of.
Residual errors. The differences between measured values and the most probable value.

EXISTENT CORNER. A corner whose position is evidenced by a monument or its accessories as described in the field note

record, or whose location can be identified by the aid of acceptable testimony.

Exposure Station. Photographic mapping: The point in space, in the air or on the ground, at which a photograph is made. Specifically, the space coordinates of the rear nodal point of the camera lens.

Exterior Orientation. Photographic mapping: The re-establishment of the relation between a photograph and the earth's surface at the time of exposure. In aerial photography its elements are the swing, the tilt, and the azimuth of the principal plane. In terrestrial photography, its elements are the horizontal angle between the optical axis of the camera and the base line, and the vertical angle between the optical axis and the horizontal ground plane. *See also* Orient.

External Distance. The distance from the vertex of a circular curve to the middle point of the curve.

Fill. Depth to which material is to be placed (filled) to bring the surface to a predetermined grade; difference in elevation between a surface point and a point vertically above it at the proposed grade. (Also called "embankment.")

Filter. Photography: A glass or gelatin plate placed in front of, in, or back of the lens, to modify on the film or plate the effect of light, of different colors, or of some particular color.

Focal Length. Photography: Distance along the lens axis between the rear nodal point of a lens and the primary focal plane. In optics, the true focal length is measured from the principal point to the focal point.

Focus. Photography: Point where rays of light meet after passing through a lens. The rays from an infinitely distant object point are incident on a lens as a bundle of parallel rays, and converge and form an image in the "primary focal plane." The point at which the lens axis pierces the primary focal plane is the "primary focal point." In all lenses used in photographic mapping the primary focal plane and focal point are the posterior, or rear, focal plane and focal point, that is, the plane and point on the side of the lens away from the object.

Conjugate Foci. Two points so related that rays from one are focused at the other.

Foresight. (1) Transit traverse: A point set ahead on line to be used for reference when resetting the transit on line or when verifying the alinement. (2) An observation of the distance and direction to the next instrument station. (3) Leveling: The reading on a rod that is held at a point whose elevation is to be determined. (A foresight is often called a minus sight because it is subtracted from the height of instrument to obtain the elevation of the point. It is not, however, essentially a negative quantity. When the rod is held inverted, as in taking levels on overhead shafting, the reading is of opposite sign to that read in the usual position because it is measured in the opposite direction from that normally used. The term "minus sight" is recommended as preferable; but the older term, "foresight," is still in general use.)

Gauss Point. *See* Principal point.

Glossy Print. Photography: A photograph with shiny or lustrous surface.

Grade. (1) Elevation of finished surface of an engineering project; (2) actual elevation, as, "crown of road at grade 59.50"; or, "sewer line, grade 21.19 at station 1 + 50.00"; (3) rate of slope or degree of inclination, as, "a 2% grade." *See also* Gradient.

Gradient. Rate of rise or fall, as "a 5% gradient," meaning 5 ft. vertical rise in 100 ft. horizontal distance (also recorded as 0.05).

Great Circle. A circle on the globe cut by any plane through its center. The equator and all meridians are great circles. On account of the spheroidal form of the earth, great circles on its surface are only approximations. Neglecting the effect of spheroidal form, any "straight line" run out with the transit is a part of a great circle.

Grid. A system of rectangular coordinate lines, usually superimposed on the projection lines of a topographic map, the Y-axis coinciding with some selected geographical meridian. It is much used for military purposes.

Grid Azimuth. The angle that any given line makes with a north-and-south grid line. It differs from the true azimuth (except at the central or initial meridian) by the amount of the convergence of the meridians.

Grid Distance. The plane distance between two points, as determined from the grid (x, y) coordinates. It may be greater or less than the corresponding ground distance.

Ground Control. *See* Control.

Ground Plane. Photographic mapping: The assumed horizontal plane to which the details of an aerial photograph are referred.

Height of Instrument (H. I.). (1) Spirit leveling: Vertical distance from datum to line of sight of instrument. (2) Stadia leveling: Height of center of transit (axis) above the station stake, or the ground beneath, which ever is used as rod point. (In the second definition the height is small and is limited by the height of the observer or his instrument. In the first definition it may be great, depending upon the elevation of the station with respect to the datum. "Elevation of line of sight," E.L.S., has been suggested as a substitute for the H. I. of spirit leveling.)

Hypersensitized Film or Plate. Photography: A film or plate which, after coating with emulsion, is specially treated to increase its speed. The effect of treatment is moderately short-lived, and the film must be kept at moderately low uniform temperature. *See also* Supersensitive film or plate.

Hypsometric Map. General term for map showing relief by any convention, such as contours, hachures, shading, or tinting. *See also* Relief map.

Image Plane. Photographic mapping: *See* Photograph plane.

Image Point. Photographic mapping: Image on a photograph corresponding to a definite object on the ground.

Image Ray. Photographic mapping: Straight line from a ground object, through the camera lens, to the image on the photograph.

Interior Orientation. Photographic mapping: The re-establishment of the relation of the plate or film to the camera lens at the time of exposure; its elements are (*a*) the two rectangular coordinates of the principal point of the photograph with respect to the arbitrary axes of the photograph, and (*b*) the principal distance of the camera lens. The assumption is made that the optical axis of the lens is perpendicular to the plane of the photograph.

Isocenter. Aerial photographic mapping: The point on a tilted photograph at the intersection of the principal line and the axis of tilt. (Sometimes called the m-point.) It is approximately midway between the plate nadir and the principal point.

Latitude, Astronomic. The angle between the direction of gravity and the plane of the equator.

Geocentric latitude. The angle between the radius vector, or line, from the place to the center of the earth, and the plane of the equator. (Latitude as shown on topographic maps and on navigators' charts is geodetic latitude.)

Geodetic latitude. The angle between the normal to the spheroid and the plane of the equator.

Latitude Difference. Length of the projection of a traverse course on to a meridian (length of course times cosine of bearing). Also called "latitude," "northing," or "southing."

LEFT BANK. The bank of a stream that is on the left when one looks in the direction in which the stream flows.

LINE MAP. *See* Planimetric map.

LINE OF SIGHT. The sighting or pointing line of a telescope, defined by the optical center of the objective and the intersection of the cross hairs. *See also* Collimation position.

LONG CHORD. See Chord.

LONGITUDE, ASTRONOMIC. The angle between the meridian plane containing (or parallel to) the plumb line at the station and the zero, or reference, meridian (usually that of Greenwich).

Geodetic longitude. The angle between the meridian containing the "normal" at the station and the zero, or reference, meridian.

LONGITUDE DIFFERENCE. *See* Departure.

LOST CORNER. A corner whose position cannot be determined, beyond reasonable doubt, either from traces of the monument, or by reliable testimony relating to it; and whose location can be restored only by surveying methods and with reference to interdependent existent corners, by mutual agreement of abutters, or by court decision.

m-POINT. Aerial photographic mapping. *See* Isocenter.

MAP. A representation to a definite scale on a horizontal plane of the physical features of a portion of the earth's surface (natural or artificial or both) by means of symbols, which may emphasize, generalize, or omit certain features as conditions may warrant. A map may be derived from ground surveys made by transit, plane table, or camera, or from aerial photographic surveys, or both. However, under this definition the aerial photographs themselves, whether prints or mosaics, cannot be classed as maps, because all points that are not in the assumed ground plane are displaced toward or from the center of the picture, and hence do not stand in the same relation to each other as they do in a horizontal projection. In order to distinguish the various maps made by aerial photography the following terms have been proposed: (*a*) aerial line map; (*b*) aerial topographic map; and (*c*) aerial stereotopographic map. The first does not show contour lines; the second does show contour lines; in the third the contours have been determined by means of stereoscopic methods. *See also* Cadastral map; Hypsometric map; Planimetric map; Stereometric map; Topographic map.

MATTE PRINT. Photography: A photograph with a dull, lusterless surface.

MEAN SEA LEVEL. The mean level of the sea at a given station; that is, the mean elevation of the tidal curve. It varies somewhat from place to place.

MEAN TIDE LEVEL. The plane, or surface, that lies exactly halfway between mean high water and mean low water (also called "half-tide level"). On account of the lack of symmetry of the tidal curve this is not exactly the same as mean sea level.

MIDDLE ORDINATE. The (radial) distance from the middle point of a chord of a circular curve to the middle point of the corresponding arc.

MIDDLE POINT (M.P.). The point on a circular curve that is equidistant from the two ends of the curve.

MINUS SIGHT. *See* Foresight.

MONUMENT. The structure erected to mark the position of a corner. Permanence is implied. In a legal sense a monument is any physical evidence of a boundary of real property.

MOSAIC. Aerial photography: An assemblage of vertical aerial photographs.

Controlled mosaic. A mosaic in which the photographs have been adjusted by reference to accurate ground control so as to produce a continuous photographic representation of a part of the earth's surface.

Uncontrolled mosaic. A mosaic in which the photographs have not been adjusted by reference to ground control.

NADIR. Aerial photography: The point on the ground plane that is vertically beneath the lens of an aerial mapping camera. (Sometimes called the "plumb point" or "ground nadir point.")

Plate nadir point. That point where a vertical ray through the rear nodal point of the camera lens pierces the plane of the photograph. (Sometimes called "photographic nadir.") The nadir point is also called the v-point; capital V usually indicates the ground nadir point, and small v the plate nadir point.

NEGATIVE. Photography: Exposed camera plate or film. A plate or film is not a negative until it is exposed; after exposure, it may be an "undeveloped" or a "developed" negative.

NODAL PLANES. Optics: Planes perpendicular to the optical axis and passing through the two nodal points.

NODAL POINTS. Optics photography: The two points on the optical axis which in theory represent the apices of the cones of rays incident on and emergent from the lens system.

Front nodal point. The nodal point of incidence.

Rear nodal point. The nodal point of emergence. Rays in the object space entering the lens in the direction of the front nodal point emerge in the image space parallel to their former direction, but as if their source had been the rear nodal point.

OFFSET. A side (horizontal) measurement of distance perpendicular to a line, usually a transit line.

OFFSET LINE. A line established parallel to the main survey line, and usually not far from it. Examples: A line on a sidewalk, 2 ft. from the established street line; a line parallel to the center line of a bridge and 50 ft. from it.

OPTICAL AXIS. A prolongation of the line joining the nodal points of a lens. It passes through the centers of the spheres whose surfaces form the boundaries of the lens.

OPTICAL CENTER. (1) Optics: That point on the optical axis intersected by a ray which emerges from the lens in a direction parallel to that in which it entered. (2) Photography: *See* Principal point.

ORIENT. (1) To turn a map or plane-table sheet in a horizontal plane until the meridian of the map is parallel to the meridian on the ground. In this position all lines on the map have the same azimuths as the corresponding lines on the ground. (2) Photography: To turn a photograph in a horizontal or vertical plane until the perspective view is in correct relation to the ground or to a map. *See also* Exterior orientation. (3) Transit: To turn the instrument so that the direction of the 0° line of its horizontal circle is parallel to the direction it had in the preceding, or in the initial, set-up.

ORTHOCHROMATIC FILM OR PLATE. Photography: A plate or film in which the color sensitivity has been extended into the green and yellow. Such a plate or film is sensitive to violet, blue, green, and yellow light.

OVERLAP. Photography: Amount by which one print overlaps the area covered by another. The overlap between aerial photographs in the same flight is distinguished as the "end lap," and the overlap between photographs in adjacent parallel flights is called the "side lap."

PANCHROMATIC FILM OR PLATE. Photography: A plate or film in which the color sensitivity has been extended through the orange into the red. Such plate or film is sensitive to visible light of all colors.

Parallax. (1) The apparent displacement, or change in position, of the cross hairs of a focusing telescope with reference to the image of an object, as the eye is moved from side to side, when the focus of the eyepiece or objective is imperfect. (2) Astronomy: The difference in direction of a heavenly body as seen from some point on the earth's surface and as seen from some other conventional point, as the center of the earth.

Stereoscopic parallax. The apparent displacement of corresponding image points on two overlapping photographs.

Peg Adjustment. A method of adjusting a spirit-leveling instrument, to make the line of sight parallel to the axis of the level tube. The difference in elevation between two pegs, or turning points, is determined by direct leveling, first with the instrument set up near one of these points; and second, with the instrument set up near the other point. This causes the error of adjustment to have its maximum possible effect on the observed difference in elevation, since the lengths of the foresights and backsights have been made as unequal as possible. The discrepancy between the two results is a measure of the error of adjustment and forms the basis for correcting it.

Phase. Triangulation: Error in apparent horizontal direction of a signal due to unequal or one-sided illumination of the signal.

Photogoniometer. Photographic mapping: An instrument for obtaining the direction of a ray from the nodal point of the camera lens to the image of any point on the photograph, by measuring the horizontal and vertical angles with reference to two perpendicular planes.

Photogrammetry. The art of making surveys or measurements by the aid of photography. Methods utilizing horizontal, vertical, and oblique views are in use, with and without the aid of the stereoscopic principle. *See also* Stereophotogrammetry.

Photograph. A positive or negative picture made by a camera on plate, film, or paper, or other medium.

Horizontal photograph. Photograph made with the camera axis horizontal.

Multiple photograph. Photograph made by means of a multiple-lens camera, the axis of the lenses of the different chambers being symmetrically arranged about a vertical axis so as to cover a wide field at simultaneous exposure in all chambers. A combined photograph may be formed by projecting the oblique views into a plane perpendicular to the axis of the camera unit and then mounting all views in such relation to one another that the equivalent of a very wide-angle single-lens photograph results.

Oblique photograph. Photograph made with the camera axis inclined intentionally at a comparatively large angle to the vertical.

Panoramic photograph. Photograph made by a ground camera mounted on a tripod and swung in a horizontal plane so as to give a continuous, wide-angle view. In some cases, the lens, rather than the camera itself, is the moving part.

Vertical photograph. Photograph made with the camera axis vertical, or as nearly vertical as is possible in an airplane. A so-called vertical photograph can be made truly vertical only by rectification by means of ground control.

Photograph Plane. The plane in the camera in which the plate or film is held. Also called image plane. It is not exactly the primary focal plane of the lens but is a plane placed so as to secure the best balance of sharp focus on all parts of the plate or film.

Photographic Nadir. *See* Nadir, Plate nadir point.

Phototheodolite. Terrestrial photographic mapping: A combination of a camera and a theodolite mounted on a tripod.

Planimetric Map. A map showing the natural or cultural features (or both) in plan only. Often called line map.

Planimetry. The plan details of a map.

Plat. A diagram drawn to scale showing land boundaries and subdivisions, together with all data essential to the description of the several units. A plat differs from a map in that it does not show additional cultural, drainage, and relief features.

Plate Nadir Point. *See* Nadir.

Plumb Point. Aerial photography: *See* Nadir.

Plus Distance. Fractional part of 100 ft. used in designating the location of a point on a survey line; as, "4 + 47.2," meaning 47.2 ft. beyond Station 4, or 447.2 ft. from the initial point, measured along a specified line.

Plus Sight. *See* Backsight.

Point of Compound Curvature (P.C.C.). The point of tangency common to two curves of different radii, the curves lying on the same side of the common tangent.

Point of Curvature (P.C.). The point where the alinement changes from a straight line or tangent to a circular curve; that is, the point where the curve leaves the first tangent.

Point of Intersection (P.I.). The point where the two tangents to a circular curve intersect. (Also called vertex.)

Point of Tangency (P.T.). The point where the alinement changes from a circular curve to a straight line or tangent; that is, the point where the curve joins the second tangent.

Precision. Degree of fineness of reading in a measurement, or the number of places to which a computation is carried. The precision of a measurement is indicated by the number of figures that apparently have been determined; in a computation the precision is shown by the number of places used. A high precision indicates that errors of observation are small, but it does not show that constant (or systematic) errors have been eliminated. The number 2.42 shows a higher precision than 2.4, but it is not necessarily any more accurate. An accurate result is one which is believed to have been freed from as much error as possible. *See also* Accuracy.

Pressure Plate. Photography: A glass plate placed in the image plane of a film camera to cause the film to lie flat during exposure.

Primary Focal Plane. *See* Focus.

Primary Focal Point. *See* Focus.

Principal Distance. Photography: The distance measured along the lens axis, between the rear nodal point of the lens and the principal point of the photograph.

Principal Line. Vertical aerial photography: Imaginary line on the photograph joining the principal point and the plate nadir. In a tilted photograph, this condition defines one and only one principal line, but in a truly vertical photograph there are an infinite number of lines that satisfy this condition.

Principal Meridian. Public land surveys: The meridian established through the initial point of a system of coordinated township boundary lines. *See also* Base line.

Principal Plane. Vertical aerial photography: The vertical plane through the exposure station containing the optical axis of the camera. In a tilted photograph, this condition defines one and only one principal plane (*i.e.*, the plane perpendicular to the axis of tilt), but in a truly vertical photograph there are an infinite number of planes that satisfy this condition.

Principal Planes. Optics: The two conjugate planes perpendicular to the optical axis for which the lateral magnification produced by an optical system is unity and positive. In the ordinary telescope or camera, they coincide with the nodal planes.

Principal Point. (1) Optics: Point of intersection of the optical axis with either of the two principal planes. (Also called Gauss point.) In the ordinary telescope or camera, the two principal points coincide with the nodal points. (2) Photo-

graphic mapping: The point where the lens axis intersects the plane of the photographic plate or, more exactly, the foot of the perpendicular from the emergent node of the camera lens to the plane of the photographic plate. (Also called Optical center.)

PRISMOID. Any solid, bounded by planes, whose end-faces are parallel. It is usually understood to include also figures whose bounding surfaces are warped surfaces.

PROFILE. A vertical section of the surface of the ground, or of underlying strata, or both, along any fixed line. On a railway or highway, the profile is usually taken along the center line, the elevations of the regular station points, and of any intermediate points where changes of slope occur, being determined by spirit-leveling. In order to exaggerate the slopes, the scale used for the elevations is usually larger than that used for horizontal distances.

PROJECTION. (1) Mapping: A geometric (or mathematical) system of constructing the true meridians and parallels, or the plane rectangular coordinates on a map. (2) Photography: The process of placing a negative or positive photograph in a projecting camera and reproducing the image on a screen or on a sensitized photographic medium.

RADIAL LINE PLOT. Aerial photographic mapping: Plot constructed from vertical aerial photographs in which lines radiating from the principal points of the photographs are used as horizontal directions to plot the image points by graphic triangulation.

RANDOM LINE. (1) A trial line, directed as nearly as may be toward a fixed terminal point which is invisible from the initial point; (2) a random traverse, that is, a traverse run from an initial to a terminal point to determine the direction of the latter from the former.

RANGE. (1) The prolongation (usually by eye) of any line to intersect a transit line, or other fixed line. Example: The side of a building or the line of a fence may be ranged on to a transit line; or on to the line of the side of another building. The point of intersection is said to be "in range with" the fence, or with the sides of the two buildings. (2) Hydrography: An established line along which soundings are taken.

RANGE LINE. Public land survey: Any meridional township boundary line.

RATIO PRINT. Photography: A photograph the scale of which has been changed from that of the original negative by photographic enlargement or reduction to fit known distances between points.

RECONNAISSANCE. A preliminary and usually rapid examination or survey of a region.

Reconnaissance map. The plotted result of a reconnaissance survey.

RECTIFICATION. Aerial photography: The process of projecting the image on a photograph to any other chosen plane of reference. This process is utilized in projecting the oblique photographs made with a multiple-lens camera into the plane of the vertical view, and in projecting tilted photographs from the inclined plane in which they were made to the horizontal plane with the aid of known positions and elevations of ground points.

REFERENCING. The process of tying in points, that is, measuring horizontal distances and angles that will locate a point (such as an instrument station) definitely and accurately with reference to near-by permanent objects, for the purpose of finding or relocating the station if it becomes disturbed or lost.

RELIEF. The variation in elevation of the ground surface. On a topographic map it may be indicated by hachures, shading, or, more accurately, by contour lines.

RELIEF MAP. Term ordinarily used in the United States for hypsometric map.

REPETITION. A process of measuring angles in which the results of successive observations of a single angle are added to each other mechanically on the graduated circle. The multiple angle, or sum angle, is read at the end of the series, and the single angle is obtained by dividing the sum angle by the number of repetitions.

RETICLE (RETICULE). *See* Diaphragm.

RHUMB LINE. A curve on the earth's surface which cuts all meridians at the same angle. Its bearing is, therefore, constant. (Also called "loxodrome," or "Mercator track.")

RIGHT BANK. That bank of a stream which is on the right when one looks in the direction in which the current flows.

SCALE. Ratio of any length on a map to the length of the corresponding line on the ground. In common usage the scale of a map is usually stated in terms of the "equivalent scale"; as "1 in. (on map) equals 40 ft. (on ground)." It may also be expressed as a fraction ("representative fraction," abbreviated R.F.), as 1 to 5,000, or $\frac{1}{5{,}000}$. Stated in this way the scale is, of course, independent of units, and applies equally well to feet, meters, or any other unit. A scale may also be indicated graphically by a line and properly subdivided ("graphical scale").

Approximate scale. Aerial photography: The ratio of the focal length of the camera to the elevation of the lens above the mean ground surface. Strictly speaking, an aerial photograph can have a uniform scale value throughout only in the event that both the ground surface and the focal plane of the camera are horizontal, conditions that are not encountered in practice, owing to the inevitable relief of the terrain and the tilt of the camera. An oblique aerial photograph has an infinite number of scales.

SEA LEVEL. *See* Mean sea level.

SEMI-MATTE PRINT. Photography: A non-glossy paper with only a faintly lustrous surface.

SETBACK. In base-line measurement, the distance by which the reference mark on a measuring plate is set back so that the end mark of the tape will fall on the next measuring plate.

SET-UP. (1) Transit or level: The instrument placed in position and leveled, ready for taking measurements; or a point where an instrument is to be or has been placed. (2) Base-line measurement: Distance by which the reference mark on a measuring plate is set ahead so that the end mark of the tape will fall on the next plate.

SIDE SHOT. Stadia: Readings or measurements taken to locate a point not on the traverse itself.

SLOPE STAKE. Stake set at the point where the finished side slope of an excavation or embankment cuts the surface of the ground. It is usually placed on a line at right angles to the center line and passing through the station point.

SPHERICAL EXCESS. The amount by which the sum of the three spherical angles of a spherical triangle exceeds 180°.

SPIRAL CURVE. Railroad or highway surveying: A curve of progressively decreasing (or increasing) radius used in joining a tangent with a simple circular curve or in joining two circular curves of different radii. (Also called transition curve.)

STADIA. (1) A method of surveying in which distances from an instrument to a rod are determined by observing the space on the rod scale intercepted by two lines in the reticule of the telescope; (2) the instrumental equipment used in such a survey. ("Stadia" is also used as an adjective, in such expressions as "stadia rod," "stadia survey," "stadia intercept," "stadia hairs," "stadia distance.")

STANDARD PARALLEL. Public land survey: A parallel of latitude, other than the base line, passing through a selected township

corner on a principal meridian, and established for the purpose of limiting the convergence of range lines that intersect it from the south.

STATION. (1) A set-up point, that is, a marked point on the ground, over which an instrument is to be placed; (2) a length of 100 ft., measured along a given line, which may be straight, broken, or curved; (3) any point on a straight, broken, or curved line, whose position is indicated by its total distance from a starting point, or zero point. For example, "Station 4 + 47.2" identifies a point 447.2 ft. from the starting point, the distance being measured along a given line.

STATION ERROR. *See* Deflection of plumb line.

STEREOCOMPARATOR. Photographic mapping: An instrument for accurately measuring the three space coordinates of a point by stereoscopic observation of two images of the same point contained in two overlapping photographs taken from two different exposure stations.

STEREOMETRIC MAP. Photographic mapping: A relief map made by the application of the steroscopic principle to aerial or terrestrial photographs. (Also called stereotopographic map.)

STEREOPHOTOGRAMMETRY. The art of surveying by stereoscopic measurements of photographs.

STEREOSCOPIC PRINCIPLE. Photographic mapping: The formation of a single, three-dimensional image by binocular vision of two photographic images of the same terrain taken from different exposure stations. With proper equipment all measurements needed in map construction can be made from this visual model.

STEREOTOPOGRAPHIC MAP. *See* Stereometric map.

STOP. Photography: *See* Diaphragm.

SUBCHORD. Any chord of a circular curve whose length is less than that of the chord adopted for laying out the curve. In a "railroad curve," for example, a subchord is a chord less than 100 ft. in length.

SUPERSENSITIVE FILM OR PLATE. Photography: A trade name for a plate or film coated with an emulsion which requires an extremely short exposure time. (Unlike the obsolete "hypersensitized" film, this material need not be kept at uniform temperature.)

SURVEY. (1) The act or operation of surveying, as, "a survey was made"; (2) the results of such an operation, that is, the assembled data, as, "the survey showed that the shore line was receding"; (3) an organization carrying on surveying operations, for example, the U. S. Coast and Geodetic Survey.

SURVEYING. Specifically, in civil engineering, the science or art of making such measurements as are necessary to determine the relative position of points on or beneath the surface of the earth, or to establish such points.

SWING. Vertical aerial photography: The angle on the vertical photograph between the principal line and the positive direction of the *Y*-axis of the photograph.

SWING OFFSET. The perpendicular distance from a point to a transit line found by holding the zero point of a tape at the given point and swinging the (taut) tape in an arc until the minimum (horizontal) distance is obtained.

TANGENT. (1) A straight line which touches a given curve at one and only one point, and which does not intersect it. (2) That part of a traverse line, or alinement, included between the point of tangency of one curve and the point of curvature of the next curve. (3) Public land survey: The line of a great circle normal to the meridian at a selected corner on a base line, standard parallel, or latitudinal township boundary.

Tangent distance. The distance from the point of curvature to the point of intersection (vertex), or from the point of intersection to the point of tangency.

TELEPHOTO LENSE. Photography: A combination of positive and negative lenses designed to obtain larger magnification of distant objects than is possible with ordinary lenses.

TIDE LEVEL. *See* Mean tide level.

TIE. Linear or angular measurements or a combination of the two made for the purpose of locating other points from points of known position. Ties may be made to connect physical objects with the survey line, or to locate the instrument point with reference to physical objects so that it can be re-established if lost. To "tie in" is to close a survey on itself or on another survey, or to locate a point by means of ties.

TIE POINT. Point of closure of a survey either on itself or on another survey.

TILT. Aerial photography: The angle between the lens axis and a vertical through the exposure station (rear nodal point of lens).

Axis of tilt. The line of intersection of the photograph plane and a horizontal plane at the same focal distance from the lens. (Note that the photograph has not been tilted on this axis, but about the rear nodal point of the lens.)

Direction of tilt. The azimuth of the normal to the axis of tilt.

TOPOGRAPHIC MAP. A scale representation, by means of conventional signs, of a part of the earth's surface, showing the culture, relief, hydrography, and, frequently, the vegetation.

TOWNSHIP. Public land survey: A unit of survey located with reference to one of a number of established principal meridians, whose boundaries are normally on cardinal courses 6 miles apart.

TRANSITION CURVE. *See* Spiral curve.

TRAVERSE. Series of distances and angles, or distances and bearings, or distances and azimuths, connecting successive instrument points of a transit, compass, or plane-table survey. A traverse may be closed or open, according to whether it does or does not return to the starting point.

TURNING POINT (T.P.). A point on which both a minus sight (foresight) and a plus sight (backsight) are taken on a line of direct levels.

v-POINT. *See* Nadir.

VACUUM BACK. Aerial photography: A perforated metal plate used in some film cameras or transformers in connection with a Venturi tube or suction pump in order to make the film lie flat.

VARIATION. Periodic or irregular changes in the declination of the magnetic needle, the chief of which are known, respectively, as secular, daily, annual, and irregular. The term is used by navigators to denote declination; it is also so used in the State of Texas.

VENTURI TUBE. Aerial photography: A device utilizing moving air currents to produce a partial vacuum in a film camera that is equipped with a vacuum back.

VERTEX (OF CURVE). *See* Point of intersection.

VERTICAL. Aerial photographic mapping: A vertical line through the exposure station, or rear nodal point.

WITNESS CORNER. A marker set on a property line leading to a corner; used where it would be impracticable to maintain a monument at the corner itself.

WITNESS MARK; WITNESS STAKE. A mark or stake set to indicate the position (approximate or exact) of a property corner, instrument station, or other survey point. A witness may be a rock, tree, or other object. Examples: (*a*) A blazed tree on the bank of a river may indicate the corner which is at the intersection of some survey line with the center line of the stream, and, therefore, cannot be marked directly; (*b*) a stake driven so as to stand out conspicuously, and marked with a station number, may witness a hub (with nail at exact station) driven flush with or below the surface of the ground.

WOOD *

AIR-DRIED. *See* Seasoning.

AMERICAN LUMBER STANDARDS. Standards embody provisions for softwood lumber dealing with recognized classifications, nomenclature, basic grades, seasoning standards, sizes, uniform workings, description, measurement, tally, shipping provisions, grade marking, tally cards, and inspection of lumber. The primary purpose of these standards is to serve as a guide or basic examples in the preparation or revision of the grading rules of the various lumber manufacturers' associations; their use as a framework for such rules will eliminate differences often existing. A purchaser in order to buy in conformity with American lumber standards must make use of association rules that are in conformity with them, as the basic standards are not in themselves commercial rules.

ANNUAL GROWTH RING. *See* Ring, annual growth.

BASTARD SAWN. Hardwood lumber in which the annual rings make angles of 30° to 60° with the surface of the piece.

BEAMS AND STRINGERS. Large pieces (nominal dimensions 5 by 8 in. and up) of rectangular cross section graded with respect to their strength in bending when loaded on the narrow face.

BIRD'S-EYE. A small central spot with the wood fibers arranged around it in the form of an elipse so as to give the appearance of an eye.

BLEMISH. Anything, not necessarily a defect, marring the appearance of wood.

BLUE STAIN. *See* Stain, blue.

BOARDS. *See* Lumber.

BOW. That distortion of a board in which the face is convex or concave longitudinally.

BOXED HEART. The term used when the pith falls entirely within the four faces anywhere in the length of a piece.

BRASHNESS. A condition of wood characterized by low resistance to shock and by an abrupt failure across the grain without splintering.

BROADLEAVED TREES. *See* Hardwood.

BROWN STAIN. *See* Stain, brown.

BURL. A large wartlike excrescence on a tree trunk. It contains the dark piths of a large number of buds which rarely develop. The formation of a burl apparently results from an injury to the tree.

CAMBIUM. The layer of tissue just beneath the bark from which the new wood and bark cells of each year's growth develop.

CELL. A general term for the minute units of wood structure. It includes fibers, vessel segments, and other elements of diverse structure and functions.

CELLULOSE. The carbohydrate that is the principal constituent of wood and forms the framework of the cells.

CHECK. A lengthwise separation of the wood, the greater part of which occurs across the rings of annual growth.

CHEMICAL BROWN STAIN. *See* Stain, chemical brown.

CLOSE-GRAINED WOOD. *See* Grain.

COARSE-GRAINED WOOD. *See* Grain.

COLLAPSE. The flattening of single cells or rows of cells in heartwood during the drying or pressure treatment of wood, characterized externally by a caved-in or corrugated appearance.

COMPARTMENT KILN. *See* Kiln.

COMPRESSION WOOD. Abnormal wood that often forms on the lower side of branches and of leaning trunks of softwood trees. Compression wood is identified by its relatively wide annual rings, usually eccentric, and its relatively large amount of summer wood, usually more than 50% of the width of the annual rings in which it occurs. Compression wood shrinks excessively lengthwise as compared with normal wood.

CONIFER. *See* Softwoods.

CROOK. That distortion of a board in which the edge is convex or concave longitudinally.

CROSS BREAK. A separation of the wood cells across the grain. Such breaks may be due to internal strains resulting from unequal longitudinal shrinkage or to external forces.

CROSS GRAIN. *See* Grain.

CROSSBAND. To place the grain of layers of wood at right angles in order to minimize shrinking and swelling and consequent warping; also the layer of veneer at right angles to the face plies.

CUP. The distortion of a board in which the face is convex or concave transversely.

DECAY. Disintegration of wood substance through the action of wood-destroying fungi.

Incipient decay. The early stage of decay in which the disintegration has not proceeded far enough to soften or otherwise impair the hardness of the wood perceptibly.

Typical or advanced decay. The stage of decay in which the disintegration is readily recognized because the wood has become punky, soft, and spongy, stringy, pitted, or crumbly.

DEFECT. Any irregularity occurring in or on wood that may lower its strength.

DENSITY. The mass of a body per unit volume. When expressed in the c. g. s. system, it is numerically equal to the specific gravity of the same substance.

DENSITY RULE. Rules for estimating the density of wood based on percentage of summer wood and rate of growth. The rules at present apply only to southern yellow pine and Douglas fir and differ slightly.

DIAGONAL GRAIN. *See* Grain.

DIAMOND. A distortion in drying that causes a piece of wood originally rectangular in cross section to become diamond-shaped.

DIFFUSE-POROUS WOODS. Hardwoods in which the pores are practically uniform in size throughout each annual ring, or decrease slightly toward the outer border of the ring.

DIMENSION. *See* Lumber.

DIMENSION STOCK. Squares or flat stock usually in pieces under the minimum sizes admitted in standard lumber grades, rough or dressed, green or dry, cut to the approximate dimensions required for the various products of woodworking factories.

DOTE (DOZE, ROT). Decay; any form of decay, which may be evident as either a discoloration or a softening of the wood.

DRY ROT. A term loosely applied to many types of decay but especially to that which, when in an advanced stage, permits the wood to be easily crushed to a dry powder. The term is actually a misnomer for any decay, since all fungi require considerable moisture for growth.

DURABILITY. A general term for permanence or lastingness. Frequently it is used to refer to the degree of resistance of a species or of an individual piece of wood to attack by wood-destroying fungi under conditions that favor such attack. In this connection the term "resistance to decay" is more specific.

EDGE GRAIN. *See* Grain.

EMPTY-CELL PROCESS. Any process for impregnating wood with preservatives or chemicals in which air is imprisoned in the

* From "Wood Handbook," Forest Products Laboratory, Department of Agriculture.

wood under the pressure of the entering preservative and then expands, when the pressure is released, to drive out part of the injected preservative.

ENCASED KNOT. *See* Knot.

EQUILIBRIUM MOISTURE CONTENT. The moisture content at which wood neither gains nor loses moisture when surrounded by air at a given relative humidity and temperature.

EXTRACTIVES. Substances in wood, not an integral part of the cellular structure, that can be dissolved out with hot or cold water, ether, benzene, or other relatively inert solvents.

FACTORY AND SHOP LUMBER. *See* Lumber.

FIBER. A wood fiber is a comparatively long ($\frac{1}{25}$ or less to $\frac{1}{3}$ in.), narrow, tapering cell closed at both ends.

FIBER-SATURATION POINT. The stage in the drying or in the wetting of wood at which the cell walls are saturated and the cell cavities are free from water.

FIGURE. The pattern produced in a wood surface by irregular coloration and by annual growth rings, rays, knots, and such deviations from regular grain as interlocked and wavy grain.

FLAKES. *See* Rays, wood.

FLAT GRAIN. *See* Grain.

FLITCH. A thick piece of lumber with wane (bark) on one or more edges.

FULL-CELL PROCESS. Any process for impregnating wood with preservatives or chemicals in which a vacuum is drawn to remove air from the wood before admitting the preservative.

GRADE. The designation of the quality of a manufactured piece of wood.

GRAIN. The direction, size, arrangement, appearance, or quality of the fibers in wood.

Close-grained wood. Wood with narrow and inconspicuous annual rings. The term is sometimes used to designate wood having small and closely spaced pores, but in this sense the term "fine-textured" is more often used.

Coarse-grained wood. Wood with wide and conspicuous annual rings; that is, rings in which there is considerable difference between spring wood and summer wood. The term is sometimes used to designate wood with large pores, such as oak, ash, chestnut, and walnut, but in this sense the term "coarse-textured" is more often used.

Cross grain. Grain not parallel with the axis of a piece. It may be either diagonal or spiral grain or a combination of the two.

Diagonal grain. Annual rings at an angle with the axis of a piece as a result of sawing at an angle with the bark of the tree.

Edge-grain. Lumber that has been sawed parallel with the pith of the log and approximately at right angles to the growth rings; that is, the rings form an angle of 45° or more with the surface of the piece.

Flat-grain. Lumber that has been sawed parallel with the pith of the log and approximately tangent to the growth rings; that is, the rings form an angle of less than 45° with the surface of the piece.

Interlocked-grained wood. Wood in which the fibers are inclined in one direction in a number of rings of annual growth, then gradually reverse and are inclined in an opposite direction in succeeding growth rings, then reverse again.

Open-grained wood. Common classification of painters for woods with large pores, such as oak, ash, chestnut, and walnut; also known as "coarse-textured."

Plain-sawed. Another term for flat grain.

Quarter-sawed. Another term for edge grain.

Spiral grain. A type of growth in which the fibers take a spiral course about the bole of a tree instead of the normal vertical course. The spiral may extend right-handed or left-handed around the tree trunk.

Vertical grain. Another term for edge grain.

Wavy-grained wood. Wood in which the fibers collectively take the form of waves or undulations.

GREEN. Unseasoned, wet.

GROWTH RING. *See* Ring, annual growth.

HARDWOODS. The botanical group of trees that are broadleaved. The term has no reference to the actual hardness of the wood. Angiosperms is the botanical name for hardwoods.

HEART, HEARTWOOD. The wood, extending from the pith to the sapwood, the cells of which no longer participate in the life processes of the tree. Heartwood may be infiltrated with gums, resins, and other materials which usually make it darker and more decay-resistant than sapwood.

HONEYCOMB. Checks, often not visible at the surface, that occur in the interior of a piece, usually along the wood rays.

IMPERFECT MANUFACTURE. All defects or blemishes produced in manufacturing, such as chipped grain, loosened grain, raised grain, torn grain, skips in dressing, hit and miss, variation in sawing, miscut lumber, machine burn, machine gouge, mismatching, and insufficient tongue or groove.

INTERLOCKED GRAINED WOOD. *See* Grain.

JOIST AND PLANK. Pieces (nominal dimensions 2 to 4 in. in thickness by 4 in. and wider) of rectangular cross section graded with respect to their strength in bending when loaded either on the narrow face as joist or on the wide face as plank.

KILN. A heated chamber for drying lumber.

Compartment kiln. A dry kiln designed to keep the same temperature and relative humidity throughout at any given time. In it the entire charge of lumber is dried as a unit, under drying conditions that increase in severity during the operation.

Progressive kiln. A dry kiln designed to provide drying conditions that increase in severity from entrance to exit. In it the unit charge is only a part of the total charge of lumber; a unit of perhaps four truckloads is moved through the kiln in a chain of several units, from day to day, with a single unit leaving and another entering at a time.

KILN BROWN STAIN. *See* Stain, chemical brown.

KILN DRIED. *See* Seasoning.

KNOT. That portion of a branch or limb that has become incorporated in the body of a tree.

Decayed knot. A knot which, owing to advanced decay, is not so hard as the surrounding wood.

Encased knot. A knot whose rings of annual growth are not intergrown with those of the surrounding wood.

Intergrown knot. A knot whose rings of annual growth are completely intergrown with those of the surrounding wood.

Round knot. A knot whose sawn section is oval or circular.

Sound knot. A knot which is solid across its face and which is as hard as the surrounding wood.

Spike knot. A knot sawn in a lengthwise direction.

LAMINATED WOOD. A piece of wood built up of piles or laminations that have been joined either with glue or with mechanical fastenings. The term is most frequently applied where the plies are too thick to be classified as veneer and when the grain of all plies is parallel.

LIGNIN. A principal constituent of wood, second in quantity to cellulose. It incrusts the cell walls and cements the cells together.

LUMBER. The product of the saw and planing mill not further manufactured than by sawing, resawing, and passing lengthwise through a standard planing machine, crosscut to length and matched.

Factory and shop lumber. Lumber intended to be cut up for use in further manufacture. It is graded on the basis of the percentage of the area which will produce a limited number of cuttings of a specified, or a given minimum, size and quality.

Yard lumber. Lumber less than 5 in. thick intended for general building purposes. *Boards.* Yard lumber less than 2 in. thick, 8 in. or more in width. *Dimension.* All yard lumber except boards, strips, and timbers; that is, yard lumber from 2 to 5 in. thick, and of any width. *Strips.* Yard lumber less than 2 in. thick and less than 8 in. wide.

MILLWORK. Generally, all building materials made of finished wood and manufactured in millwork plants and planing mills. "Millwork" includes such items as inside and outside doors, window and door frames, blinds, porch work, mantels, panel work, stairways, moldings, and interior trim. It does not include flooring, ceiling, or siding.

MOISTURE CONTENT OF WOOD. Weight of the water contained in the wood, usually expressed in percentage of the weight of the oven-dry wood.

MOISTURE GRADIENT. A condition of graduated moisture content between the successive layers of a material, such as wood, due to the losing or absorbing of moisture. During seasoning the gradations are between the moisture content of the relatively dry surface layers and the wet layers at the center of the piece.

OPEN-GRAINED WOOD. *See* Grain.

PECK. Pockets or areas of dinintegrated wood caused by advanced stages of localized decay in the living tree. It is usually associated with cypress and incense cedar. There is no further development of peck once the lumber is seasoned.

PITCH POCKET. An opening extending parallel to the annual rings of growth usually containing, or having contained, pitch, either solid or liquid.

PITH. The small soft core occurring in the structural center of a log.

PLAIN-SAWED. *See* Grain.

PLANING-MILL PRODUCTS. Products worked to pattern, such as flooring, ceiling, and siding.

PLYWOOD. A piece of wood made of three or more layers of veneer joined with glue and usually laid with the grain of adjoining plies at right angles. Almost always an odd number of plies are used to secure balanced construction.

POCKET ROT. Advanced decay which appears in the form of a hole, pocket, or area of soft rot usually surrounded by apparently sound wood.

PORE. *See* Vessel.

POSTS AND TIMBERS. Pieces of square or approximately square cross section, 4 by 4 in. or larger in nominal dimensions graded primarily for use as posts or columns but adapted to miscellaneous uses in which strength in bending is not especially important.

PRESERVATIVE. Any substance that, for a reasonable length of time, will prevent the action of wood-destroying fungi, borers of various kinds, and similar destructive life when the wood has been properly coated or impregnated with it.

PROGRESSIVE KILN. *See* Kiln.

QUARTER-SAWED. *See* Grain.

RADIAL. Coincident with a radius from the axis of the tree or log to the circumference.

RATE OF GROWTH. The rate at which a tree has laid on wood, measured radially in the trunk or in lumber cut from the trunk. The unit of measure in use is number of annual growth rings per inch.

RAYS, WOOD. Strips of cells extending radially within a tree and varying in height from a few cells in some species to 4 in. or more in oak. The rays serve primarily to store food and transport it horizontally in the tree.

RING, ANNUAL GROWTH. The growth layer put on in a single growth year.

RING-POROUS WOODS. A group of hardwoods in which the pores are comparatively large at the beginning of each annual ring and decrease in size more or less abruptly toward the outer portion of the ring, thus forming a distinct inner zone of pores known as the spring wood and an outer zone with smaller pores known as the summer wood.

ROT. *See* Decay.

ROTARY-CUT VENEER. *See* Veneer.

SAP. All the fluids in a tree, special secretions and excretions, such as gum, excepted.

SAPWOOD. The layers of wood next to the bark, usually lighter in color than the heartwood, $\frac{1}{2}$ in. to 3 or more in. wide, that are actively involved in the life processes of the tree. Under most conditions sapwood is more susceptible to decay than heartwood; as a rule, it is more permeable to liquids than heartwood. Sapwood is not essentially weaker or stronger than heartwood of the same species.

SAWED VENEER. *See* Veneer.

SEASONING. Removing moisture from green wood in order to improve its serviceability.

Air-dried or air-seasoned. Dried by exposure to the air, usually in a yard, without artificial heat.

Kiln-dried. Dried in a kiln with the use of artificial heat.

SECOND GROWTH. Timber that has grown after the removal by any means of all or a large portion of the previous stand.

SHAKE. A seaparation along the grain, the greater part of which occurs between the rings of annual growth.

SHOP LUMBER. *See* Lumber.

SIDE CUT. The term used when the pith is not present in a piece.

SLICED VENEER. *See* Veneer.

SOFTWOODS. The botanical group of trees that have needle or scalelike leaves and are evergreen for the most part, cypress, larch, and tamarack being exceptions. The term has no reference to the actual hardness of the wood. Softwoods are often referred to as conifers, and botanically they are called gymnosperms.

SPECIFIC GRAVITY. The ratio of the weight of a body to the weight of an equal volume of water at some standard temperature.

SPIRAL GRAIN. *See* Grain.

SPLIT. A lengthwise separation of the wood, due to the tearing apart of the wood cells.

SPRING WOOD. The portion of the annual growth ring that is formed during the early part of the season's growth. It is usually less dense and weaker mechanically than summer wood.

STAIN, BLUE. A bluish or grayish discoloration of the sapwood caused by the growth of certain moldlike fungi on the surface and in the interior of the piece; made possible by the same conditions that favor the growth of other fungi.

STAIN, BROWN. A rich brown to deep chocolate-brown discoloration of the sapwood of some pines caused by a fungus that acts similarly to the blue-stain fungus.

STAIN, CHEMICAL BROWN. A chemical discoloration of wood that sometimes occurs during the air drying or the kiln drying of several species, apparently caused by the oxidation of extractives.

STAIN, SAP. *See* Stain, blue.

STRENGTH. Broadly, all the properties of wood that enable it to resist different forces or loads. In its more restricted sense, "strength" may apply to any one of the mechanical properties, in which event the name of the property under consideration should be stated, thus: strength in compression parallel to the grain, strength in bending, hardness, etc.

STRIPS. *See* Lumber.

STRUCTURAL TIMBER. Pieces of wood of relatively large size in which strength is the controlling element in their selection and use. Trestle timbers (stringers, caps, posts, sills, bracing, bridge ties, guard rails); car timbers (car framing, including upper framing, car sills); framing for buildings (posts, sills, girders, framing joists); ship timbers (ship timbers, ship decking); and cross arms for poles are examples of structural timbers.

SUMMER WOOD. The portion of the annual growth ring formed during the latter part of the yearly growth period. It is usually more dense and stronger mechanically than spring wood.

TANGENTIAL. Strictly, coincident with a tangent at the circumference of a tree or log, or parallel to such a tangent. In practice, however, it often means roughly coincident with a growth ring.

TEXTURE. A term often used interchangeably with grain. It refers to the finer structure of the wood (*see* Grain) rather than the annual rings.

TIMBER, STANDING. Timber still on the stump.

TIMBERS. Lumber 5 in. or larger in least dimension.

Timbers, round. Timbers used in the original round form, such as poles, piling, and mine timbers.

TRACHEID. The elongated cells that constitute the greater part of the structure of the softwoods (frequently referred to as fibers); also a portion of some hardwoods.

TWIST. A distortion caused by the turning or winding of the edges of a board so that the four corners of any face are no longer in the same plane.

VENEER. Thin sheets of wood.

Rotary-cut veneer. Veneer cut in a continuous strip by rotating a log against the edge of a knife in a lathe.

Sawed veneer. Veneer produced by sawing.

Sliced veneer. Veneer that is sliced off by moving a log, bolt, or flitch against a large knife.

VERTICAL GRAIN. *See* Grain.

VESSELS. Wood cells of comparatively large diameter which have open ends and are set one above the other forming continuous tubes. The openings of the vessels on the surface of a piece of wood are usually referred to as pores.

VIRGIN GROWTH. The original growth of mature trees.

WANE. Bark, or lack of wood or bark, from any cause, on edge or corner of a piece.

WARP. Any variation from a true or plane surface. Warp includes bow, crook, cup, and twist, or any combination thereof.

WAVY-GRAINED WOOD. *See* Grain.

WEATHERING. The mechanical or chemical disintegration and discoloration of the surface of wood that is caused by exposure to light, the action of dust and sand carried by winds, and the alternate shrinking and swelling of the surface fibers that come with the continual variation in moisture content brought by changes in the weather. Weathering does not include decay.

WOOD PRESERVATIVE. *See* Preservative.

WORKABILITY. The degree of ease and smoothness of cut obtainable with hand or machine tools.

WORKING OF WOOD. Change in the dimensions of a piece of wood with change in moisture content.

YARD BROWN STAIN. *See* Stain, chemical brown.

YARD LUMBER. *See* Lumber.

SPECIFICATIONS INDEX

For costs, see Costs Index, p. 324.

For drawings and tests, see related specifications.

COSTS INDEX